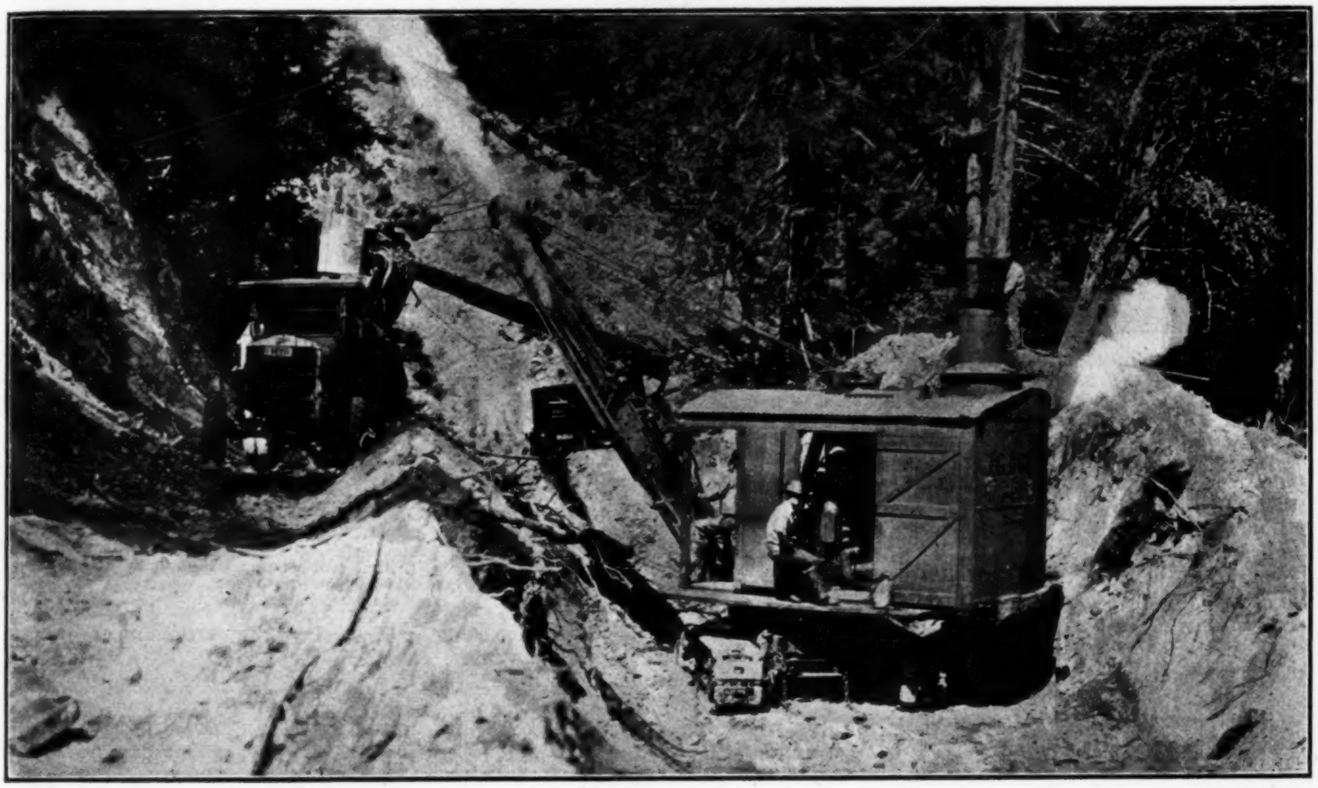
# ROADS AND STREETS

Vol. LXIX APRIL, 1929 No. 4

# Production Studies On Highway Construction

## Suggestions for Increasing Output on Grading and Paving


By WM. A. BLANCHETTE

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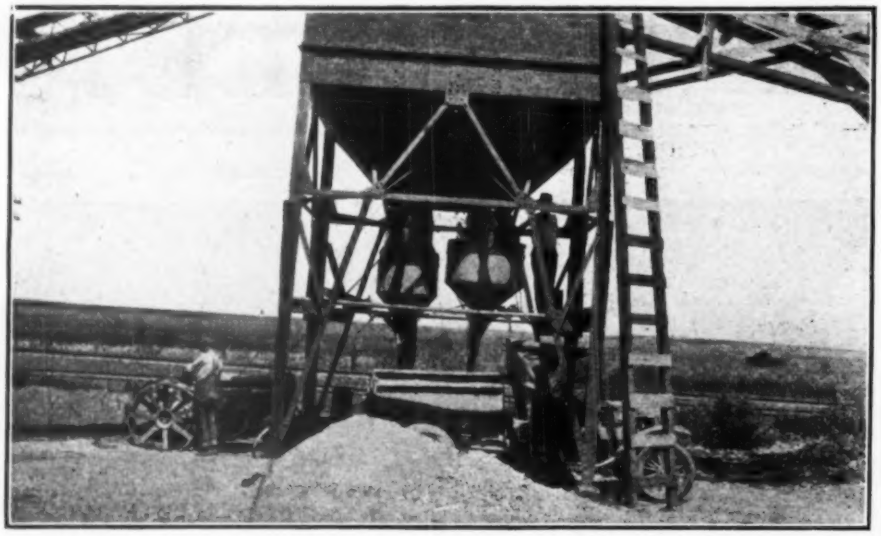
I HAVE been asked to tell you something of the work the Bureau of Public Roads is doing in conducting production studies of highway construction. Many of you, no doubt, are familiar with this work and some of you may have had men on your jobs making these studies. For those of you who are unfamiliar with our work, I shall endeavor to give an outline of what it consists of and how it applies to the highway contractor's operations.

Studies of construction methods and equipment are conducted in all parts of the United States and include nearly all types of highway construction projects, including portland cement concrete, asphaltic concrete, sheet and sand asphalt and bituminous macadam pavements. The grading work includes power shovels, elevating graders, and wheeler and fresno outfits. Studies are made of both steel and concrete bridge construction. Miscellaneous studies include drilling and blasting operations, aggregate crushing plants, etc.

**Purpose of Work.**—Primarily this work is used as a training course for the young engineer entering the employment of the Bureau of Public Roads. Each year the bureau selects from twenty to thirty student engineers from the various engineering colleges of the country. These young engineers are placed on going highway construction projects, and under the supervision of older men who have had experience in this work, they make production studies of equipment and methods pertaining to modern highway construction. They study the efficiency with which each major piece of equipment operates and the efficiency with which every operation is performed. They have, also, an opportunity to study the contractor's problems and to learn, first-hand, the practical limitations of construction work.

After these engineers have completed this course of training which extends over a period of about two years, during which time they cover the various types of highway construction work, they are assigned to duty in the district offices of the Bureau.

**How the Study Is Conducted.**—In general the study of a highway construction project is conducted in the following manner: We shall take a concrete paving project for example. On this type of project the paver is the key equipment. Every auxiliary operation should be so regulated that the paver can operate at maximum capacity. With a one-minute mix specification a modern concrete paver can mix 48 batches of concrete per hour. The difference between this and any lower rate of production is due to



Batcher Plant Set Up So That Trucks Can Drive Through Without Turning or Backing

delays. The total delay may be made up of one or more large delays when the paver ceases to operate or it may be made up of a series of small delays, many of which are too small to detect without the use of a stop-watch but which may, and often do, amount to several hours of lost time during the day and to several days during the construction season. In our production studies the operations of the major pieces of equipment are timed with a stop-watch. The mixer is timed from one to several hours a day. These studies show the exact time that is spent in mixing batches and the cause and extent of every delay during the timing period. Similar studies are made of the operation of the hauling equipment and of the operations at the loading plant.

These timing studies (each one of about one hour's duration) are made at times when the major equipment is operating and do not usually include delays of more than 15 minutes' duration. In addition to this record of operation, a general operating record is kept that shows the cause and extent of every delay of over 15 minutes' duration throughout each available working day. These large time losses are usually caused by such items as equipment repairs, unfavorable weather conditions wet subgrade, moving location, etc. A detailed study of this kind extending over a period of several weeks, gives an accurate record of the utilization of available working time and the causes and amount of the large time losses. A summary of the stop-watch studies covering the same period shows the efficiency of major equipment performance during the time that it is actually in operation. The time losses, both large and small, are usually divided into the avoidable and unavoidable class.

A study of a power shovel grading project is made in a manner similar to that of the paving outfit. Here production should be regulated by the capacity of the shovel. The maximum production of a power shovel is not constant like the maximum production of a concrete paver. The shovel production varies with the kind of material handled, the depth of cut, angle of swing, etc. The cause of a production rate lower than the maximum (for any governing set of conditions) can be traced to specific delays. They may be large delays when the shovel stops moving excavation entirely, or they may be a series of small delays that occur with every operation of the dipperload cycle, but that total several minutes of each hour and several days of the construction season.

The power shovel is timed from one to four hours during each day that the study is being made. The results show the time taken to perform each operation of the dipperload cycle—loading, swinging, dumping and returning—for different kinds of materials, depths of cut and angles of swing. They show the time spent in handling execavation and the causes and extent of all delays. Every operation connected with the hauling equipment is studied in a similar manner. The general record of operation gives the larger time losses.

**Facts Disclosed on Power Shovel Operation.**—This is only a general outline of one major phase of the work. Many different studies are made and many research investigations are carried on; but since equipment operation and production is what you are interested in, I shall outline some of the results of these studies.

A summary of production studies made of the operation of 71 power shove grading projects during the past three seasons in all parts of the United States is as follows: Total hours available for operation, 16,996. Actual hours that equipment operated, 12,046, or 71 per cent of the available working time. The 4,950 hours that were lost are composed of delays of over 15 minutes' duration. The delays that are to a great extent avoidable under proper management are:

| | Per Cent |
|---|---|
| Moving shovel | 3 |
| Drilling and blasting | 2 |
| Hauling equipment | 1 |
| Water and fuel | 1 |

The delays that are more or less unavoidable are:

| | Per Cent |
|---|---|
| Shovel repairs | 10 |
| Unfavorable weather and wet grade | 9 |
| Miscellaneous delays | 3 |

During the 12,046 hours that these 71 shovels were actually in operation they were timed with a stop-watch for 1,760 hours. During this timing period 674 hours, or 38 per cent of the stop-watch study time, was lost through small delays of less than 15 minutes' duration. The avoidable delays are:

| | Per Cent |
|---|---|
| Faulty operation of hauling equipment | 7 |
| Inadequate supply of hauling equipment | 8 |
| Moving shovel | 3 |
| Checking grade | 3 |
| Taking on fuel and water at wrong time | 1 |
| Operator | 1 |

Typical Rough Condition of Hauling Road on Average Grading Job

The unavoidable delays are:

| | Per Cent |
|---|---|
| Shovel repair | 3 |
| Moving shovel | 2 |
| Handling rocks and stumps | 3 |
| Blasting | 1 |
| Handling traffic | 2 |
| Miscellaneous delays | 4 |

It is reasonable to assume that the operation of these power shovels is fairly typical of power shovel operation in general. The outstanding delays are common to nearly all projects. This means, therefore, that the average power shovel outfit actually operates only 71 per cent of that part of the construction season during which it is actually on the job, and that during the time that it is operating it loses 38 per cent of the time through small delays, the greater part of which can generally be avoided through proper management.

**Data on Concrete Paving Project.**—You will probably be interested in the data that has been collected on concrete paving projects. A summary of the results obtained on 44 concrete paving projects during the past two years in all parts of the United States is as follows: Total time available for paving during observations, 20,168 hours. The time that the crew actually worked mixing and placing concrete was 11,665 hours, or only 58 per cent of the available time. One-half of this lost time is caused by delays that can generally be avoided through proper management. They are:

| | Per Cent |
|---|---|
| Inadequate supply and faulty operation of the hauling equipment | 3 |
| Mixer trouble | 2 |
| Lack of materials | 4 |
| Lack of water at the mixer | 2 |
| Delays at the loading plant | 2 |
| Lack of prepared subgrade | 4 |
| Miscellaneous delays | 4 |

The remaining delays can be classed as unavoidable. They are:

| | Per Cent |
|---|---|
| Rain | 9 |
| Wet grade | 9 |
| Moving the plant set up | 3 |

On these 44 projects timing studies were made of mixer operation for 1,510 hours during the 11,665 hours that concrete was being poured. Four hundred and one hours, or 27 per cent of this timing period, were lost through small delays of less than 15 minutes' duration. Most of these delays could have been avoided under proper management. They are:

| | Per Cent |
|---|---|
| Inadequate supply of hauling equipment | 5 |
| Faulty operation of the hauling equipment | 5 |
| Inadequate water supply | 4 |
| Lack of materials | 4 |
| Mixer trouble | 2 |
| Faulty operation of the mixer | 2 |
| Finishing concrete | 2 |
| Lack of prepared fine grade | 2 |
| Miscellaneous delays | 1 |

Assuming that the operation of these outfits is typical of concrete paving operations in general, the average outfit mixes concrete only 58 per cent of that part of the available working time that it is actually on the job, and loses 27 per cent of the time that it is in operation through small delays of less than 15 minutes' duration.

Effective Width of Road Reduced by Allowing Boulders to be Strewn along the Side

**Importance of Eliminating All Avoidable Delays.**—The labor and equipment cost per day for operating a power shovel grading outfit varies but little whether the production is 300 cu. yd. or 1,000 cu. yd. On a modern concrete paving job the same equipment and the same organization is used whether the paver mixes 100 batches or 400 batches per day. The value of eliminating all avoidable delays whether they are large or small can readily be appreciated. The summaries that have been given show that the average highway contractor's outfit operates only about two-thirds of the available working time during that part of the construction season that he is on the job, that part of this lost time can be utilized through better planning, and that about one-third of the time that he is working is lost through small delays, most of which can be eliminated. These facts are not to be construed as being critical. There are time losses in all work, but it is this particular phase of time losses that is of most importance to the highway contractor. Unit prices for construction work are, to a certain extent, fixed. The daily cost of labor and equipment is practically constant regardess of production. The contractor's profits depend on his ability to eliminate waste time.

We have studied concrete paving outfits that turned out better than 40 batches of concrete for every hour the paver operated during the season. Other outfits have been studied that did not average 20 batches per hour. The same wide variation in the rate of production exists on power shovel grading jobs. On some jobs studied each shovel averaged better than 80 cu. yd. of common excavation for every hour it operated. On other jobs operating under the same conditions and excavating the same kind of material the shovels did not move 30 yd. per hour. The difference between the high and the low rate of production on both concrete paving and power shovel grading projects did not lie in any marked difference in the capacity or condition of the equipment. Modern pavers were used in all cases. The power shovels were modern, with practically the same power and capacity. The difference did not lie in the labor or auxiliary equipment requirements. The rate of production in all these cases varied directly with the ability of the management to utilize available working time.

**Relation of Production Studies to Contractor's Operations.**—As I have stated before, the primary purpose of this work is to train young highway engineers entering the employment of the bureau in modern methods and practices pertaining to highway construction; to give them this training on going construction projects where they can observe the factors which affect both quality and production in this work, and where they can study the contractor's problems from a practical standpoint. A secondary purpose of this work, and one which is growing in importance, is to furnish the highway contractor with the results of these production studies with the hope that they may assist him in reducing time losses and increasing production.

It is sometimes stated that studies of this kind are too theoretical; that they are not applicable to construction work; that the delays that cause a low rate of production must occur and that they cannot readily be eliminated. That this is not the case and that a detailed study of the job is the most practical way of showing exactly how the outfit is running has been proven on many jobs where the contractor used the results of these production studies as a guide in reducing his time losses, especially the small persistent losses which, on many projects, account for more lost time than do the large delays when the equipment is not operating. Unless the causes of low production are known, they cannot be eliminated, and they cannot readily be ascertained through casual observations.

If the highway contractor would have a similar daily production study made of his job as a part of his regular operation, there is no doubt but that the results will show that these studies are not only practical but that they are essential for efficient operation. The data collected in this way would guide superintendents and foremen in their efforts to eliminate delays; they would tend to develop an efficient personnel; and they would keep the main office in direct contact with every operation. A contractor's cost accounting system gives the daily unit cost for each operation. A study of this kind will show why the unit cost is what it is.

The process of laying a concrete

Finishing Operation on a Concrete Paving Job

pavement is composed of a number of different operations. The mixer should set the pace and all the other operations should be so conducted that the mixer will turn out the maximum possible number of batches per hour. To accomplish this requires planning and constant supervision over every detail.

The daily rental cost for equipment on the modern paving outfit is in the neighborhood of $250. The daily labor cost is about this same amount, making the operating cost for labor and equipment approximately one dollar for every minute of the working day. This cost does not vary much whether 800 sq. yd. or 2,000 sq. yd. of pavement are laid during the day, but the difference in the labor and equipment cost of a 20-ft. pavement between these two rates of production amounts to $4,396 per mile. There are many paving outfits that do not average 400 lin. ft. of 9 in., 6 in., 9 in., 20-ft. pavement per day. We have observed outfits that averaged better than 1,000 lin. ft. of similar type pavement for every day the paver operated.

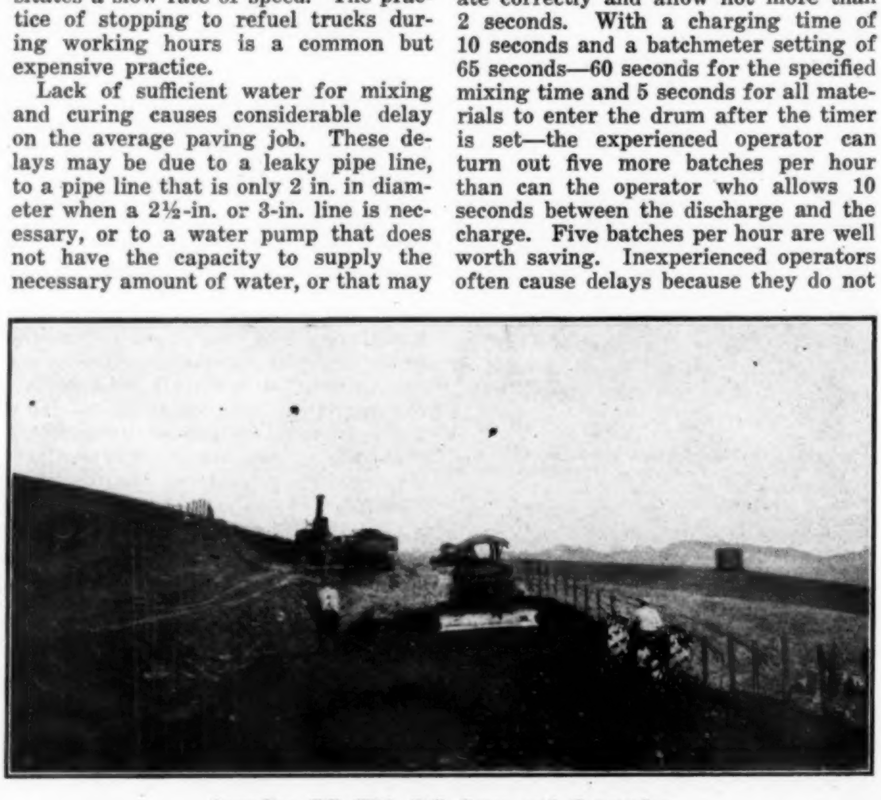
**Causes of Low Production.**—There are many causes for a rate of production lower than the maximum. Lack of a sufficient number of hauling units to supply the mixer with the maximum number of batches it can mix per hour is one of the outstanding causes of delay on nearly every paving project. The paver works a few minutes and then has to stop until more batches arrive. There is a small delay between every few batches. These delays often go unnoticed, but it is not uncommon for an outfit to lose one or two hours a day through these small interruptions. It is an easy matter to determine the neccesary number of hauling units required for any length of haul. It is difficult to justify excessive time losses of this type when the cost of two or three minutes of idle time at the mixer will pay the hourly rental charge on an additional truck.

The operation of the hauling equipment deserves considerable attention, for delays in this operation not only delay the paver but also raise the cost of hauling. It is not always possible to keep the trucks from bunching up at the paver and at the plant, especially when trucks of different makes and capacities are used. It is essential, however, that the trucks be kept moving and that unnecessary operations be avoided. Loading plants so arranged that the trucks can drive under the batcher, receive their loads and then drive directly to the cement loading platform and out of the plant without the necessity of turning and backing can save considerable truck time. A few dollars spent on keeping the hauling road in condition is money well spent. It is not uncommon to see trucks running in low or second gear, not because the going is heavy, but because the roughness of the road necessitates a slow rate of speed. The practice of stopping to refuel trucks during working hours is a common but expensive practice.

Lack of sufficient water for mixing and curing causes considerable delay on the average paving job. These delays may be due to a leaky pipe line, to a pipe line that is only 2 in. in diameter when a 2½-in. or 3-in. line is necessary, or to a water pump that does not have the capacity to supply the necessary amount of water, or that may be worn out and continually breaking down. It often happens that the mixer operator has to wait between every batch for the mixer water tank to refill before he can mix the next batch. Small delays of this kind do not seem important, but they often total several minutes in the day.

Under many conditions it is essential that a sufficient amount of aggregate and cement be stockpiled to take care of the uncertainty of shipments. Excessive time losses are sometimes caused by lack of materials at the plant.

**Lost Time in Mixer Operation.**—Unless the operator is familiar with the correct manner of operating the mixer, he can be the cause of considerable lost time. Handling a batch of concrete consists of three different operations: charging the drum, mixing and discharging. Charging, the time to raise the skip from the ground to the vertical or stop position, is regulated by the design of the mixer. It takes between 8 and 10 seconds to perform this operation. Specifications regulate the length of mixing time. The discharging operation can be overlapped with charging. That is, an experienced operator will start the discharge at the instant the timing device sounds. At about the same time he will start raising the mixer skip, allowing only 1 or 2 seconds between the two operations. The discharge gate is closed a second or two before the skip reaches the vertical position. It is more common for operators to allow 10 seconds between the discharging and charging operations than to find those who operate correctly and allow not more than 2 seconds. With a charging time of 10 seconds and a batchmeter setting of 65 seconds—60 seconds for the specified mixing time and 5 seconds for all materials to enter the drum after the timer is set—the experienced operator can turn out five more batches per hour than can the operator who allows 10 seconds between the discharge and the charge. Five batches per hour are well worth saving. Inexperienced operators often cause delays because they do not



Spreading Fill With Bull Dozer and Compacting

properly place and spread the concrete. This makes unnecessary work for the puddlers and finishers, and the paver often has to stop until the finishing operations catch up.

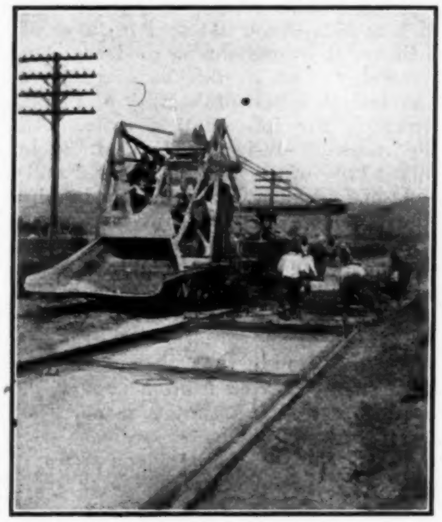
Another delay that is persistent on many paving projects is caused by a failure to properly prepare the fine grade ahead of instead of in the rear of the mixer. Attempting to prepare the fine grade behind the mixer usually causes a delay every time the mixer moves.

**Lost Time on Power Shovel Grading.**—The daily cost of labor and equipment on a power shovel grading job is about $100, exclusive of hauling, drilling and blasting, and varies only a small amount regardless of production. The value of regulating every auxiliary operation so that the shovel can move excavation is apparent. Yet, on the average job a couple hours a day are lost through small avoidable delays.

Chief among these, and one that exists on nearly every job, is the delay caused by an insufficient supply of hauling equipment. When the shovel is not casting, it can excavate only as much material as can be hauled away. A delay of a few seconds or a minute between each truck or wagon load does not appear to be an important matter; but, when it is considered that it takes only about a minute to load 3-yd. truck with common excavation, a 30-second delay between truck loads reduces possible production by 33 per cent. A few dipper loads of excavation will pay the hourly rental charge of an extra hauling unit.

Maintaining the hauling road so that the hauling equipment can operate efficiently is another item that is neglected on nearly every job. The rate of speed of trucks on a grading job is only about 3 or 4 miles per hour. This rate can usually be doubled with a small amount of maintenance on the hauling road. The cut is often excavated too narrow and the fill built too narrow for the hauling units to pass each other. A widened place or turn-out where the hauling units can pass is often so far behind the shovel that it takes as long to exchange hauling units at the shovel as it does to load a unit. This one item often cuts production in half. Often the effective width of a sufficiently wide cut or fill is considerably reduced by allowing gasoline drums, boulders and stumps to be strewn along the hauling road.

A shovel operator, as a rule, is reliable, yet there are many ways in which an experienced operator can save money for the contractor. The four principal operations connected with power shovel excavation are: loading the dipper, swinging, dumping and returning the dipper in position for another load. In common excavation the average time to perform each of these operations is approximately: loading, 7 seconds; swinging, 6 seconds; dumping, 2 seconds; returning, 5 seconds, or a dipper load every 20 seconds. These figures are given merely to show that each operation takes only a few seconds and that each one is performed several hundred times during the day. An operator who takes one or two seconds longer than is necessary to perform each of these operations can easily cost the contractor several times the operator's daily wage. It is essential that the hauling equipment be spotted at the shovel so that the angle of swing will be as small as possible. It takes about 5 seconds for a shovel to swing through an angle of 90 degrees and about 8 seconds for it to make a swing of 180 degrees. Whenever it is possible to do so, the loading should be done at the side of the shovel instead of at the rear. An item like this usually goes unnoticed, but when it is considered that a saving of four seconds per dipper load (by reducing the angle of swing) when the output is about 100 dipper loads per hour, means a saving of about one hour of working time during the day, its importance is magnified.



An Interesting Paving Job

Another item that is worth mentioning is the importance of excavating cuts and building fills to the proper line and grade. On many of the grading projects that we have studied the shovels moved over the same sections of the road several times before the sections were finally built to the proper grade. In most every case of this kind it is much cheaper to excavate to grade the first time through a cut. Doing the work in this manner reduces the cost of clean-up work and tends to make a better road for the hauling equipment.

In order to operate at a high degree of efficiency, it is necessary to have proper supervision over every operation. Without this the best equipment will not produce. A superintendent who understands construction work, who realizes the value of eliminating waste and who knows how to eliminate it, is invaluable to the highway contractor. Without supervision of this kind it is difficult to secure increased production.

Our contact with the highway contractor has been invaluable to us in this training work. Contractors' organizations in all parts of the United States have given us excellent cooperation. It is hoped that we can be of service to you in furnishing the data that we are collecting. Any suggestions that you can make for bettering this service will be appreciated.

To date several articles on this work have been published in "Public Roads," the official publication of the Bureau. These articles can be obtained from the Bureau's office at Washington, D. C.

**Acknowledgment.**—The foregoing paper was presented March 13 at the annual convention of the New York State Highway Chapter of the Associated General Contractors of America.

## Motorists Favor Building Secondary Highways

Uniformity of traffic regulations, licensing of all automobile operators and the building of secondary highways are today the three major requirements of the motorists of the United States, according to a poll of motor club officials attending the recent annual convention of the American Motorists' Association.

A comprehensive program, embracing all together fifteen problems of primary importance to the motorists of the country, was adopted by the national motoring body at the conclusion of its two-day session which, in addition to the three already named, included wider state highways; by-pass routes diverting through traffic around congested cities; employment of traffic circles, rather than intersections, wherever possible; regional highway planning; abolition of railroad grade crossings where possible, and where not practical, the installation of mechanical safeguards; placing of traffic bureaus, in large cities, under competent highway engineers; universal adoption of the Hoover Model Traffic Code; eliminaton of solid tire vehicles from public highways; highway safety education in all public schools; ultimate acquisition by the public of all major toll bridges; Federal regulation of interstate bus traffic, and opposition to the fee system of fining motorists for traffic regulations.

The legislative program of the association for this year, it was voted, is to be primarily centered upon securing Federal and State financial support of secondary highways which are tributaries to main routes of automobile traffic. The need for state legislatures authorizing the establishment of ultimate rights of way for highways of a width adequate to meet future traffic necessities was also pointed out.

# Weighing the Probable Truth of a Theory

By HALBERT P. GILLETTE, Editor

THERE is a prevalent belief that men equally informed as to the facts are equally competent to weigh the merits of a scientific theory; but the history of science shows that a very large percentage—usually a great majority—of scientists have not been competent to appraise a new theory.

Newton's theory of gravitation was not generally accepted in Europe until long after his death. Prout's theory of the genesis of atoms from hydrogen was rejected by all authorities for nearly a century. Einstein's theory of relativity was practically ignored by scientists for 15 years after its publication. Each of these three theories was supported by quantitative evidence that should have carried conviction the instant the theory and the evidence were grasped. These three are typical of scores of quantitative theories that have had to wait decades, or even generations, before general acceptance was secured.

After making allowances for mental inertia, skepticism, egotism and all the psychological conditions that prevent an impartial and thorough study of a new theory, a good deal of mystery remains as to the slowness with which a true theory receives general approval. It will not do to attribute such slowness to commendable scientific caution, especially where the evidence was overwhelming when the theory was first announced. We must look for other reasons.

In searching for other reasons I have come upon one that seems to explain most of this phenomenon of skepticism about new theories. It is the prevalent failure to test new theories by the laws of probability. Treatises on logic usually discuss such tests in the most perfunctory manner, if they discuss them at all. Treatises on probability are often but little better, for their authors usually seem to have scant appreciation of the power of the science of probabilities in testing theories, to say nothing of its usefulness in discovering natural laws.

Of the 90 known atoms (out of the 92 that are supposed to exist) about one-quarter have atomic weights that are integral numbers. When, in 1815, Prout announced his theory that hydrogen atoms are the "bricks" of which the other atoms are built, the percentage of the then known atoms that possessed weights that were integral multiples of that of hydrogen exceeded 25 per cent. Let us assume, however, that 10 atoms in 40 exactly corresponded with Prout's theory. What was the probability of its truth? If any atom selected at random had an atomic weight that was an integral multiple of that of hydrogen, the probability that it would have such a weight merely by chance would be excessively small. But let us assume that it would be 1 in 2; or that it either would or would not have an integral weight. Then if 10 random selections from the 40 resulted in finding 10 atoms having integral weights, the probability of this happening purely by chance would be only 1 in 2 to the 10th power, or 1 in 1,004. Since there were 40 atoms, the fact that only 10 of the 40 had integral weights, would reduce the probability to 1 in 251. Even 251 to 1 in favor of a theory is overwhelming evidence; but remember that in this case we have assumed an initial probability of 1 in 2, which is far too small a ratio. All the possible weights that an atom might have other than an integral multiple of hydrogen, are so nearly infinite that we have no means of estimating them. When, therefore, we say that the chance is even that an atomic weight will be an integral multiple of hydrogen, we are grossly over-estimating that chance. Indeed so gross is our over-estimate that we are safe in saying that if even 2 atoms out of 90 have weights that are integral multiples of one another, they are almost certainly related as causes of one another, or a concomitant resultants of a common cause.

But the chemists looked only at the instances where Prout's theory seemed to fail, and never weighed the significance of the instances where it held true; so they rejected the theory for a century. Recently it has been found that where atoms have fractional weights, they are mixtures of isotropes that have integral weights. Thus chlorine has an atomic weight of 35.46 as a result of the mixture of three isotropes of chlorine whose weights are 35, 37 and 39. So the very exceptions that were cited against Prout now are seen to prove his rule.

Were this an isolated instance of the misjudging of a scientific theory by all the authorities save its originator, it should at least serve as a warning to skeptics. But it is not isolated. On the contrary, scientific history swarms with similar instances. Of course the initial evidence in favor of many a new theory is relatively weak, but actually the degree of its weakness is rarely demonstrated by an appeal to the law of probabilities. Instead, the critics merely guess that it is weak; and usually their guesses are influenced by its apparent failure to agree with some known fact or facts, rather than by its proved agreement with several known facts.

When any theory is in close quantitative accordance with even a very few facts, it is rare that it fails to show a very high degree of probability if tested by the laws of probability.

One celebrated astronomer, commenting on the slowness with which Newton's law of gravitation was accepted, says that this slowness was not surprising because Newton had not shown its accordance with very many astronomical facts. This statement is clear evidence of this astronomer's ignorance of the use of the laws of probability in testing such a theory; for, had Newton only proved that his law held true of the earth and the moon, still that proof would be very convincing to anyone familiar with the elementary principles of probabilities. But Newton's law fitted Kepler's laws so perfectly that he had thus extended it to include all the known planets; and he had also carried it far enough to explain quantitatively the height of the ocean tides. Truly it is astounding to find any astronomer hesitating to accept such proof as conclusive.

If it be argued that Newton wrote when science was in its infancy, the answer is Einstein's experience. Einstein offered in proof of his relativity theory that, by its aid, he had deduced two laws previously deduced by Lorentz, who in his deduction, had used the well established principles of electrodynamics. That alone was proof overwhelming that Einstein's relativity theory must be sound. But Einstein added one of the most spectacular tests of a theory that has ever been published. He deduced, by his theory, the 43 secs. of arc per century through which Mercury's orbital axis rotates, in excess of the rotation accounted for by Newton's laws; and his deduction agreed with the fact within the observational error. Yet this marvelous proof of his theory caused scarcely a ripple of interest in a scientific world which, 25 years later, is all agog over Einstein's latest development of the same theory. It is true that one of Einstein's original predictions was found to be correct 10 years ago, and that this awakened the attention of the scientific world. But this itself shows a surprising ignorance of what constitutes a crucial test of a theory. To predict a future occurrence accurately is certainly spectacular, but it is not a whit more difficult than to deduce from a theory a quantitative result in accordance with any known fact that was not used in deriving the theory. Einstein's deduction of Mercury's known orbital change was just as conclusive evidence of the truth of his theory as was his deduction of the amount by which a ray of light bends when it passes near the sun. That thousands of modern scientists failed to appreciate that this is so, is one of the most conclusive proofs that few of them know how to weigh evidence scientifically.

There is great need, therefore, of study of the principles of probability, and particularly of their application to measuring the worth of new theories. In a later article I will indicate the use of the science of probability in discovering natural laws.

# Method of Financing the System of Roads in Chile

## How a South American Republic Is Providing for Highways

By ABRAHAM ALCAINO

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CHILE is formed by a longitudinal valley 2,100 miles long and 140 miles wide bounded by the Province of Tacna on the north and the Territory of Magallanes on the south; from parallel 18 deg. to parallel 55 deg. This valley lies between the Andes on the east and the Pacific Ocean, with a smaller chain of mountains on the west. These two mountains are continuously joined by smaller hills, down the sides of which run clear and permanent streams.

Due to the fact that the country lies between parallels 18 deg. and 55 deg. and that its entire coast is bathed by the Pacific Ocean its climate is one of the most delightful in the world. Its climate is very much like that of California, although the maximum and minimum temperatures in Chile are more moderate.

The northern zone is very dry. It has very little rain and the maximum summer temperature reaches only 40 deg. centigrade. This zone is called "La Pampa" Chilean nitrate of soda is extracted in this section.

The central zone has rain only in the winter time during the months of May, June, July and the first part of August. There is no snow at any time in its valleys, and frosts are rare, and the temperature very seldom goes below zero centigrade.

In summer time the maximum temperature never passes 35 deg. centigrade and this temperature is only reached around noon. The breeze from the Andes to the Pacific Ocean prevents an exaggerated heat and many times it is really cold at night.

The rainy season in the southern section also occurs during the winter but it begins in May and ends in August. The maximum rainfall is not too much and its longer period of duration has permitted an extraordinary growth in the vegetation. The rivers are quite wide and are used very much for the navigation of boats of small tonnage.

**The Lakes and the Canal Zone.**—This is the southern zone and possibly is the prettiest of all from the tourist's point of view. Ex-President of the United States Mr. Theodore Roosevelt, after visting this part of Chile, said: "That the other beauties of the world only brought to his recollection the beauty of this part of Chile."

**Center of Population.**—The population of Chile has been estimated today at 6,000,000 and the most important centers of population are found far away from the capital of Chile, Santiago, the most important city in the country, with a population of 600,000 inhabitants. In this city the government and congress, the most important banks, universities, and other institutions are located. Valparaiso, Chile's largest port, is the second city in importance, with a population of 350,000 inhabitants, and is 180 kilometers from Santiago. Apart from these two important cities we find, starting from the north: Antofagasta, with a population of 130,000, the principal port for the shipment of nitrate of soda; Concepcion, south of Sanitago, near the splendid port of Talcahuano, is in an agricultural and industrial region. Among its activities can be found coal mines, clothing factories, sugar-refining companies, steel mills, etc. It has its own important university, being one of the principal centers of culture in Chile. It has a population of about 95,000. Valdivia is a river port on the Valdivia River, and is a great industrial center as well as a great resort for tourists. It has a population of 100,000.

**Census of Traffic and Road Classification.**—The topography and the distribution of the country's population had a decided influence on the formation of the plans for roads, its order of construction and improvement.

By means of the census it has been established in a scientific and clear way what the principal currents of the actual traffic are and what the approximate future ones will be.

With this data, and keeping in view the coordination of the national systems of transportation, river and sea, railroads and existing roads, a road plan has been prepared in categorical order and immediate importance:

1. Roads giving access to centers of consumption.
2. Roads uniting centers of consumption.
3. Roads giving access to railroad stations.
4. Roads giving access to ports or other roads of exportation.
5. Roads of development and tourist.
6. International roads.

I will give a short explanation of the two last divisions.

**Roads of Development and Tourists.**—Chile has great agricultural resources, mines and forests in various southern provinces that today are inactive because of the lack of permanent communication.

It happens that these regions are perhaps the most picturesque and practical for the development of tourist traffic, and at the same time they are also close to various important centers of the Republic of Argentina.

The roads will be built in the Province of Cautin, Valdivia, Chilos and in the Aysen Territory.

**International Roads.**—Although these roads have been classified last in the construction plan of the roads department of Chile, this department assigns to them a great deal of importance and for a long time has been working for their construction. We have three principal international roads: One toward the Peruvian frontier which, in part, is the same as the longitudinal highway that unites Sanitago with the various northern provinces. This route is open, but is old and unimproved. It is now being improved.

Toward the Argentina frontier we have two roads of great importance under construction. One in the north, starting from the city of Los Andes, will unite with Mendoza, Argentina, and the other in the south in the lake region, passing through the most beautiful scenic section and taking advantage of nature in a capricious manner, sometimes road and sometimes by ferry across the lakes. Both roads will be completed in 1930.

**Explanation and Application of the Road Law.**—After the year 1920, in which the laws for roads were approved, improvements of the highways were accomplished exclusively by the general funds of the nation, its amount being very small and hardly sufficient to keep the roads in repair during the summer time.

With the road act of March, 1920, our highway history really begins.

Although in practice we have noted many times the error of conceding the right of interference to a great number of diverse organs of government, which has made the application difficult, but the law is good and easy to control.

The government grants a territorial subsidy of \$2 per \$1,000 of assessed property value, for the benefit of the roads and the money must be invested

in the same region in which it has been collected.

Outside of this contribution there are others of minor importance, such as mining licenses, fines for infractions of the road laws, and a Federal contribution equal to double of all voluntary individual contributions.

This law has produced the following quantities from 1920 to 1928:

| | Chilean Pesos |
|---|---|
| 1920 | $ 1,120,875.54 |
| 1921 | 8,431,128.78 |
| 1922 | 8,578,060.30 |
| 1923 | 10,160,690.72 |
| 1924 | 11,939,057.99 |
| 1925 | 14,802,000.06 |
| 1926 | 15,365,032.63 |
| 1927 | 19,403,150.42 |
| 1928 | 23,000,000.00 |
| Individual contribution, 1920-1928 | $40,000,000.00 |
| Total invested from this law | $152,999,906.44 |

**Bridge Law.**—As a complement of the road law the bridge law was approved in 1925, on the basis of the following principle incomes:

1. Duty on the importation of oil and gasoline.
2. License tags for horse and ox-drawn vehicles.
3. Tax on animals sold at fairs.
4. Tax on animals driven to the fairs.

This law has produced very good results and its income increases each year.

Income

| Produced | Chilean Pesos |
|---|---|
| 1925 | $ 3,084,697.75 |
| 1926 | 10,087,584.74 |
| 1927 | 11,215,756.67 |
| 1928 | 15,000,000.00 |
| Total | $39,388,039.16 |

This income permits the maintenance of a permanent construction program of 40 bridges each year all reinforced concrete.

**Funds from Special Laws.**—The road system of Chile embraces around 40,000 kilometers, of which 5 per cent may be used the year round, the remainder may be used only during the summer, that is, when there is no rain.

The ordinary income from the road law and the aids from the annual budget of the nation, are insufficient to obtain the construction of the part of the principal system that the economic development actually requires. And on the other hand, it is not possible to postpone for much time the definite solution of this problem, and they have secured large sums of money by means, that is by loans, to serve as special resources.

During the year 1928, the following loans for roads have been authorized:

| | Chilean Pesos |
|---|---|
| 1—Loans for roads giving access to Santiago | $ 27,000,000 |
| 2—Loans for different roads | 95,000,000 |
| 3—Loans for different roads | 90,000,000 |
| 4—Aid from the National Budget | 95,000,000 |
| Total | $307,000,000 |

To this sum must be added also $15,-000,000, Chilean Pesos, that will be the probable amount received from the road law, when discounted by 35 per cent for the service of the loan and a special quota equal to 15 per cent for the purpose of obtaining machinery and for administration.

Therefore, the total sum authorized for the construction, maintenance, acquisition of machinery and road surveying, amounts to $322,000,000 Chilean Pesos, or $40,000,000 American dollars.

For the amortization of these loans the following quantities must be discounted:

1—$95,000,000 aid from the National Budget.

2—$15,000,000 funds of the law.

Therefore the amount that must be amortized is $212,000,000.

Supposing that we should request the entire amount immediately with the 10 per cent, including interest and amortization, we would need an annual income for the service of this loan of $21,200,000 Chilean Pesos.

Nevertheless, these funds will be divided and invested during a period of five years, and the loans will be invested at home at 7 per cent, or abroad at 6 per cent and their amortization will be accumulative at 1 per cent annually.

The financing of the loans will be carried out with the following special resources:

1. Up to 35 per cent of the annual income from the road loan law.
2. With an additional right to an import duty on gasoline and oil of $0.05 (Chilean money) at net kilo.
3. With a sale tax on automobile and trucks.
4. With a fee for operators, license of 10 pesos per year.
5. With toll from different roads.
6. Aid from the national budget equal to the income from items 2, 3 and 4.
7. With the interest that these amounts produce.

**Income From the Resources**

1. Territorial tax (property tax) ........ 2 per cent
   Territorial assessed valuation ........ $15,000,000,000
   Territorial tax, 2 per cent ........ 30,000,000

$10,500,000 Pesos, 35 per cent for service of loans.

2. Gasoline Import Duty, $0.03 per kilo.
   Average importation of gasoline in the last three years is 40,-000, kilos. Suppose an increase of 15 per cent, or an importation annually of 46,000,000 kilos. The tax of $0.05 per kilo will produce

2,300,000 Pesos.

3. Tax on sale of motor vehicles, $300 each. The latest statistics indicate an importation of more than 4,000 autos per year, with a tendency to increase rapidly. Supposing an average importation of 5,000 autos per year we will have an income of

1,500,000 Pesos.

4. License fee for operators, $10 per year. The actual number of automobiles in the country is 25,000, and taking into consideration an annual increase of 5,000, we will have in 1929 a total of 30,000 and an income of

300,000 Pesos.

5. Tolls.
   Tolls are charged on the roads giving access to Santiago and Valparaiso, in which are invested around $60,000,000 (pesos). We may estimate that with a toll charged sufficiently low, there may be obtained 5 per cent annually on the capital invested in its construction. If there is invested $20,000,000 pesos annually we will obtain an income on tolls of

1,000,000 Pesos.

6. Aid from the National Budget.
   The National Budget proportions an annual aid equal to the income obtained from items numbers 2, 3 and 4 ($2,300,000), ($1,500,000), ($300,000), or that is

4,100,000 Pesos.

7. Interest on these funds.
   As this plan of construction will last five years, we may suppose that in the first year there will be invested $122,000,000 pesos and that the balance of $200,000,000 will be deposited in a bank at 4 per cent per annum, amounting to

8,000,000 Pesos.

$27,700,000 Pesos Total Income.

It will be seen that the financing of the different loans is assured in excess to allow for a depreciation of 3 per cent on the bonds, besides these items of resources will automatically increase when the system of improved roads begins to be given over to traffic; while at the same time the service of them will be annually decreasing.

If after accomplishing the service of the debt a surplus remains, this will be allotted to the floating of new internal loans for the construction of more roads.

**Manner of Executing the Work.**—The execution of all the works authorized by these special laws or loans will be allowed by contract for a lump sum to the lowest bidder, allotted at a public bidding in conformity with the plans, bases, specifications and definite taxes created by the Department of Roads of the Ministry of Development and approved by the President of the Republic.

Urgent works, and those for which no definite studies have been made, will be accomplished by the piece work system, limited by the amount of work in the project which has already been studied.

The government will only carry out works itself when the amount of the contemplated expenditures is less than $200,000 pesos and when after two calls for bids no interested parties appear.

**Acknowledgment.**—The above paper was presented Jan. 16 at the 26th annual convention of the American Road Builders' Association.

# Surface Treatment Application

## Methods and Cost in Tennessee

By F. W. WEBSTER

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In Tennessee the type of road surface that is treated consists of either water-bound macadam, gravel, or chert. At least 90 per cent of the mileage treated has been limestone macadam. These roads generally have been maintained by continuous dragging with a road machine, using a thin layer of fine stone as floating material, which material is continuously moved by the road machine to maintain a smooth riding surface. Roads of this type, when well maintained, present very smooth riding surfaces, but in dry seasons, especially Summer and Fall, become very dusty for travel exceeding 300 cars per day.

**Materials.**—Two kinds of bituminous material are used in treatment of this type. One is an asphalt, which has been cut back with naphtha, the finished material having a specific viscosity of between 15 and 30. The other is a similar cut back tar. Only one grade of stone chips are used, which consists of well graded stone passing a 1¼-in. screen, and retained on a ½-in. screen.

**Cleaning the Surface.**—Immediately before the bituminous material is to be applied, the road surface is very carefully cleaned, until it is entirely free from all loose material and all dirt. This is usually accomplished by the use of a rotary broom. Very excellent results are also obtained, in some cases, by the use of a mechanical blower, following the broom, which machine blows away, in a cloud of dust, all loose, fine particles which the broom may fail to remove. Almost no hand work is used in cleaning the road surface.

**Application of Bituminous Material.**—After thorough cleaning of the road surface, the bituminous material is applied to the surface through a distributor, at a uniform rate, which, in Tennessee, is either 0.3 gal. per square yard, or 0.4 gal. per square yard, depending upon the design for the particular job. In general, two designs are used, one requiring a total average of 0.7 gal. of bituminous material and 50 lb. of chips in two applications, and the other requiring a total of 0.9 gal. of bituminous material and 75 lb. of chips. The bituminous material is applied cold, except that in cool weather it is sometimes necessary to apply a small amount of heat, to secure a consistency in the material that will provide free flowage through the distributor nozzles. Immediately after application of the bituminous material, there is applied to the road surface from 15 to 20 lb. of stone chips per square yard, of the gradation previously outlined, the exact amount depending on the design used. The road surface is then carefully bladed, generally by using a One Man (motor driven) grader, every square yard of the surface being covered by the blade of the grader. The effect of this blading is to fill most of the small depressions in the road surface with stone chips, to thoroughly coat the chips with bituminous material, and to improve the riding qualities of the road. Traffic is allowed to use the road during both applications. The process of blading is continued until the bituminous material, after evaporation of all the volatile oils, becomes too stiff for further blading to continue, without permanently marring the road surface. The time between application of the bituminous material and the end of blading operations is usually about forty-eight hours. This application is usually termed the "prime coat."

**The Second Application.**—In general, the second application can be successfully applied at any time, between three days and one year after the first application is made. However, we believe that we obtain a smoother riding road at less expense by applying the second application as soon as possible after the first. In Tennessee then, the second application is usually applied within one week of the first. Its method of construction is as follows. Directly upon the surface of the road, which has been treated as previously described, is spread a very uniform layer of stone chips, of the gradation described previously. These chips are spread upon the road directly by trucks, some of which have a patented device attached which closely regulates the height of tail gate and the discharge of stone. However, many trucks are not equipped with these devices and the quantity of stone desired and remarkably uniform distribution is obtained, with skillful, and practiced drivers, who secure very closely the proper distribution by regulation of their speed. For the lighter design, 35 lb. of chips per square yard are used, while for the heavier, 55 lb. are used. The chips are then very carefully and lightly bladed with a road machine, after which bituminous material is applied through a distributor at the rate of 0.4 gal. per square yard for the lighter and 0.5 gal. per square yard for the heavier treatment. Traffic is allowed to use the road during all operations. The road is then continuously bladed for about 48 hours, until the bituminous material becomes too stiff for blading. It is then rolled thoroughly with either a 5 or 10-ton roller until well compacted. Any raveled spots which may develop during all these operations are patched, and any lean spots have additional bituminous material applied, if and when they develop. In my mind, the outstanding feature of this treatment is the continuous blading process used in both applications, which results in the construction of a remarkably smooth riding surface.

**Costs.**—This treatment is being built in Tennessee both by state forces and by contract. The lighter treatment, using 0.7 gal. bituminous material and 50 lb. of chips is costing approximately 20 ct. per square yard. The heavier treatment, using 0.9 gal. of bituminous material and 75 lb. of chips, is costing approximately 25 ct. per square yard. In one division of the state the total cost of cleaning the road surface, hauling and applying the bituminous material, hauling and applying the chips (average haul one mile), blading and rolling, has been 2.7 ct. per square yard, of which total the detailed costs are divided as follows:

| | Per Cent |
|---|---|
| Sweeping and cleaning | 15.2 |
| Hauling and applying oil (average haul 3 miles) | 21.5 |
| Hauling and applying chips (average haul 1 mile) | 45.4 |
| Blading | 10.2 |
| Rolling | 7.7 |

**Acknowledgment.** — The foregoing paper was presented at the 7th annual Asphalt Paving Conference.

# Enforcement of Material Specifications

## How a County Bureau of Tests Operates

By P. J. FREEMAN

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THE originator of that classic phrase—"It's a great life if you don't weaken" must have been a highway materials engineer. Nothing can destroy the usefulness of an inspection department more quickly than the lack of firmness on the part of the engineer in responsible charge of such a department. Only a man with long training in the business of inspection of materials can recognize at once those things which require firmness in order to preserve the life of the inspection system and at the same time he must be able to differentiate from those things which, although important in the matter in hand, do not lend to ramifications if moderate concessions are made.

All inspectors must be fair and just to the material producers, the contractor and the purchaser. Only properly trained engineers, chemists and inspectors know enough to be fair as well as honest. Such men know the percentage of error in sampling and testing a given material and do not reject materials through errors in testing or snap-judgment. Granted that the material does not comply with the specifications governing the contract, then the inspection department must keep such material out of the work, even though they have to fight every construction engineer on the job in addition to the material producer and the contractor. Change the specifications when a new contract is to be let, but do not "weaken" in the enforcement of specifications governing a contract which is already under way.

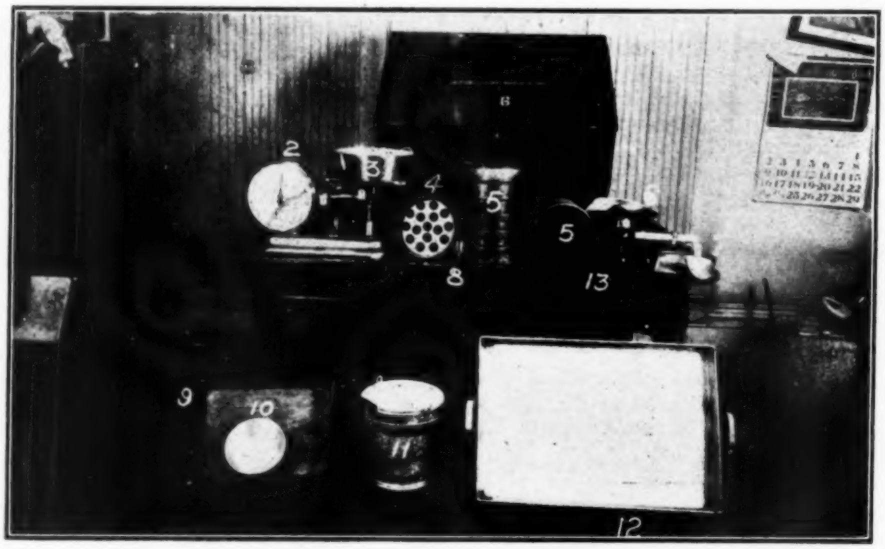
**Specifications Must Be Enforced.**—Specifications for materials must be developed with a thorough knowledge of the sources of supply as well as the quality of the materials suitable for any particular kind of work. It is not fair to expect an inspection bureau to enforce specifications written by engineers who are not specialists in materials and therefore are not capable of writing a specification which can be enforced. The cooperation of the construction divisions with the inspection bureau should develop specifications which cover available materials suitable for the work in hand and thus the necessity for changes in specifications is eliminated.

**Allegheny County Bridge and Road Builders' Program.**—About 30 years ago the United States War Department ordered certain bridges in Allegheny County, Pennsylvania, raised. This was not done and a controversy raged for many years. Permission was not granted by the War Department to build new structures or change the location of piers under the old bridges until the requirements from Washington had been fully complied with. This meant that the bridge building program was not developed and after the Liberty Vehicular Tunnels had been constructed at a cost of about $5,000,000 it was not possible to build a bridge over the river to carry the traffic into the city of Pittsburgh. In 1924 the Commissioners of Allegheny County selected Norman F. Brown as Director of a Department of Public Works to be organized by him. The writer and several other consulting engineers joined the new organization and assisted in the development of a department of public works with some features which we believe to be different from such departments in other municipalities. A bond issue of $29,000,000 was floated and the money spent for bridges and roads during the past four years and we are now starting on a new program covering approximately $50,000,000. This statement is made in order to explain why a county should find it necessary to have an inspection bureau such as was established.

**Allegheny County Department of Public Works.**—Since the entire Department of Public Works was new there were few old prejudices to overcome and no antiquated equipment to be used. The new Department of Public Works was organized with four principal Bureaus—Roads, Bridges, Architecture, and Tests and Specifications. The Bureau of Roads and Bridges had been in existence under a different form of organization and the personnel was enlarged to take care of the additional work. These bureaus also have their own maintenance divisions. The Bureau of Architecture and the Bureau of Tests and Specifications were newly organized.

**Bureau of Tests and Specifications.**—It was recognized that a bureau of tests as usually organized does not carry sufficient authority to properly enforce specifications. Frequently the head of the testing bureau is not even consulted in the preparation of specifications and methods proposed in the specifications for the enforcement of the requirements for materials. It was felt that a bureau of tests and specifications would carry responsibilities and opportunities for service to the other bureaus much greater than is possible under the usual system of organization.

In establishing a bureau of tests and specifications it is necessary to obtain the cooperation of the construction bureaus whose heads have been writing specifications without regard to those used by other bureaus, and endeavoring to enforce them without sufficient assistance. They should be given to understand that the knowledge of the engineers, chemists and inspectors is always available for advice on every problem coming up in construction as well as in the writing of specifications. In order to obtain this cooperation a very definite policy should be established and the word passed around that




Asphalt Plant Inspector's Field Equipment, Allegheny County

the representatives of the bureau of tests and specifications are not detectives whose duty it is to detect failures to comply with the specifications after the work has been done. Unless they are active enough in following out their obligations to prevent bad materials from going into the work, they have failed in the purpose for which such a bureau was established. It is far better to spend time in testing materials, accurately setting a batcher plant, and in requiring the contractor to have adequate equipment for doing a job before he starts the work than it is to find that the contractor has been cheating after the work is under way.

The full value of a bureau of this character is not reflected in the number of tests completed nor in the rejection made of unsuitable material. Assistance should be given to the material producers and contractors in obtaining satisfactory materials and incorporating them in the work. Rejecting unsatisfactory material is a negative producer involving trouble and loss for all concerned. The prevention of the shipment of such material to the job is constructive cooperation. This does not mean that inspectors shall always test and approve materials before they leave the plant of the producer, but through cooperation with the producer he is given to understand exactly the quality and kind of materials required and usually his own inspection forces can prevent materials from being shipped which would be rejected after arrival on the job.

**Scope of Bureau of Tests and Specifications.**—The writer developed the activities of the new bureau from past experience with commercial testing laboratories and state highway departments, keeping in mind that service to all other bureaus should be given freely and cheerfully.

The field of the bureau of tests and specifications extends throughout all activities of the department of public works—its organization is of such a nature that it works harmoniously in cooperation with the other bureaus which have come to regard the bureau of tests and specifications as a clearing house for tests pertaining to the adaptability of materials they desire to use. Briefly stated, some of the activities of the bureau members are as follows:

1. Approve all sub-contracts for materials and sub-contractors.

2. Writing specifications for materials and equipment and cooperation with Bureau of Bridges, Roads and Architecture in the preparation and correlation of specifications to insure uniformity in materials and methods.

3. Giving instruction to inspectors in the field concerning methods for testing materials.

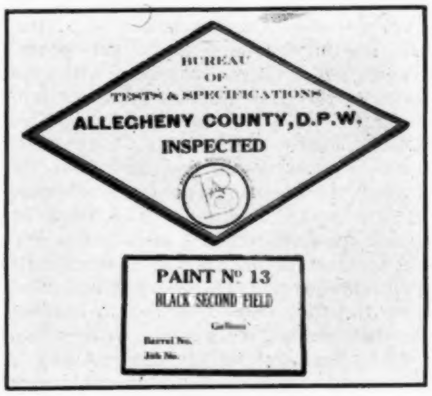
4. Design and construction of field-testing equipment and furnishing same to various bureaus.

5. Testing materials and controlling mixtures at all asphalt plants owned by Allegheny County as well as contractors' plants furnishing asphaltic concrete for contract jobs.

6. Preparation of specifications, tests and inspection of paints, oil, gasoline, bituminous materials, bearing metals, railroad ties, switches, paint brushes, water-softening plants, boilers, pumps, lumber, metal signs, etc.

7. Complete mill and shop inspection of all steel, bronze, steel-castings, and other materials used in the construction of highway bridges.

Approval monthly of all estimates for metals used in bridges, both as to quality and quantity before payment is made.



Official Stamp of the Bureau

8. Inspection of all materials used in the maintenance of roads and bridges and checking the invoices against the actual tests made on that particular shipment before county comptroller will approve bill for payment.

9. Drilling cores from all pavements and making a joint report with bureau of roads to accompany final estimate before payment is approved by the county comptroller.

10. Membership on active committee of national engineering and chemical societies and cooperating with such organizations in research in materials of construction.

Summarizing information obtained from such societies and making it available to construction bureaus.

**Authority to Enforce Specifications.**—It seems needless to say that the head of a bureau of tests and specifications must have complete backing from the highest executive in the organization and some provision should be made in the system of handling payment for the work so that the responsibility for the final estimate is a joint one with the construction division or bureau. In our case all current estimates for steel used in bridge construction are approved monthly for quantity and are checked to see that the material listed in the invoices has been tested and approved by the Bureau of Tests and Specifications. When a pavement has been completed this bureau sends a core drilling machine over the job taking samples at intervals and a joint report is made by the Bureau of Roads and the Bureau of Tests and Specifications stating the results determined by the core drill and recommendations for payment. Until this joint report has been received for the final estimate the county comptroller will refuse to approve payment. This gives an opportunity for the inspection bureau to enforce the requirements of the specifications while work is in progress which it would not have if it were unable to exert a financial pressure on the contractor.

**Method Used for Enforcement of Specifications.**—The specifications of Allegheny County require the contractor to submit in writing, immediately after signing the contract, information as to whom he proposes sub-letting any portion of the contract, whether for materials or labor or both. Officially the county does not deal with any sub-contractor, but the main contractor who is under bond to the county is required to be responsible for the quality of all materials purchased by him. In actual operation, however, we have our ordinary dealings directly with the sub-contractors and material producer unless these dealings are such that they should come through the original contractor. This method is pursued so long as the material producer is cooperating with us and furnishing satisfactory materials, but if he fails to do so, he is immediately ignored and pressure exerted on the main contractor which will require him to obtain a new source of supply if necessary.

The specifications further require the contractor to furnish representative samples before placing his orders, and he must apply in writing for permission to purchase materials from any given source, and approval in turn will be given him in writing if that source of supply is satisfactory and capable of furnishing the material. The following extracts from our specifications give what we believe to be the keynote of the combination for enforcement of material specifications.

"After the approval of source of supply of the material has been obtained the contractor shall immediately furnish two copies of the order for this material to the Bureau of Tests and Specifications. All orders shall carry the notation—This material must meet the requirements of Allegheny County specifications and is subject to inspection by the Bureau of Tests and Specifications."

"When required by the director the contractor shall furnish invoices showing the total quantity of cement shipped for use on our contract together with a statement of the amount used and unused."

The specifications further require the contractor to furnish all material for testing and under certain circumstances he must store and handle concrete specimens as prescribed under the specifications.

**Approval of Sub-Contracts.**—It is

needless to say that in granting approval for the placing of sub-contracts for concrete materials, reinforcing steel, paving brick, asphalt filler, crack filler, etc., that such approval must be based solely upon the ability of the material producer to furnish such materials promptly and of a quality which will comply strictly with the specifications. This work is handled solely by engineers who are "technical" appointees and in no way directly responsible to political influences. If the main contractor requests permission to place a sub-contract with a material producer who has never furnished such material to Allegheny County, a representative of the bureau makes a careful inspection of his facilities for furnishing such materials, whether it be for incorporation in concrete or for construction of bridges. The material producer is definitely informed concerning the requirements of the specifications and he is therefore in a position to furnish such materials if he obtains his sub-contract.

We have found that material producers are quite willing to install new screens for properly grading stone or make similar arrangements in order to produce materials complying with the specifications, provided they do not yet have the contract. The approval of the sub-contract is therefore contingent upon the sub-contractor's agreement to do certain things necessary for the proper preparation of his material or the delivery of same.

This procedure immediately brings the main contractor and his sub-contractors into direct relations with the Bureau of Tests and Specifications and they are thus brought to realize that the material specifications are to be enforced.

During the past four years the bureau has inspected about 30,000 tons of metals for bridges each year and this method of requiring definite approval for the dozens of sub-contractors on a large bridge has made it possible to say that no part of such a structure was incorporated unless it complied with the specification.

**Correlation of Specifications.**—By correlating specifications so that every bureau uses exactly the same kind of material in the same way for similar purposes, it is possible to enforce specifications more readily. We also found that by adopting the Pennsylvania State Highway Specifications for materials which were available in our district we had the assistance of a large user of materials. Producers knew state requirements and were equipped to furnish such materials of a quality required by the state. We also endeavored to have the city of Pittsburgh and surrounding boroughs adopt the same specifications and to a considerable extent this has been done. By thus eliminating some of the varieties of material prescribed by different municipalities a more uniform product was obtained by all concerned.

**Identification of Jobs and Samples.**—At the time a project is advertised it is given a consecutive job number which covers that contract. All samples of every kind connected with that contract bear the job number in addition to the number of the particular sample. This simplifies clerical work in the office and makes it impossible to confuse samples from jobs having similar names. All reports are filed under the job number and a triple index makes the file readily accessible.

**Listing Jobs and Material to Be Tested.**—When the contract is signed the job number and name are posted on a large sheet together with the name of the contractor and the resident engineer assigned to the job. This sheet carries every item of material used in construction and each item required on a given contract is checked in the proper column. The data on which the final letter is sent to the contractor instructing him to communicate with the bureau are recorded and likewise the first date on which he replies. A separate tickler system calls attention to the first letter sent out and if that does not start the new contractor to writing letters he is given a second chance and then the construction bureau is notified. Even though materials are to be used for some time the contractor is not allowed to proceed by the resident engineer until an armistice has been signed by the Bureau of Tests and Specifications and the contractor who usually hunts us up as quickly as gasoline can get him there.

The contractor then knows exactly what is required, even though he never read the specifications before bidding on the work, and he has no excuse for failure in the future to comply with the requirements of our specifications.

When tests are started on any particular material the fact is noted on the sheet and from then on the clerk's records in the laboratory keep the testing going at the proper intervals. The use of this sheet is based upon the theory that most of the sins of a contractor are those of omission and we have found that the contractors are willing to co-operate and can usually assign their stenographer or purchasing agent to the duty of keeping us properly advised concerning permission to place sub-contracts and furnishing copies of orders. It is necessary to leave nothing to the contractor which can readily be directed from the bureau and a glance at the sheet shows materials which have not been placed under test for the first time.

The resident engineer on each job should see that every material used has been properly tested and approved, but this system serves to enforce the specification in case the resident engineer fails to do so and it is also an assistance to him on account of the fact that the man in the field has many construction details to occupy his time.

**Keep the Work Going.**—It is our policy to keep the testing done ahead of the need for material, even though it requires overtime and Sunday work. If this contractor orders these materials in plenty of time the tests can usually be completed with ease. The use of the sheet listing the jobs and materials enables an engineer in the Bureau of Tests and Specifications to anticipate the requirements of the contractor and his attention is called to the fact that we have not yet received copies of his orders for such materials. Even though there are fifty or more projects going at one time it takes but a few minutes to check over the materials being tested for all. The chief engineer of the bureau and his assistant are constantly driving over the county inspecting each job under construction and therefore the bureau head is in constant touch with the progress of each piece of construction. The Bureaus of Construction make a daily report to the Director of Public Works, with copies to the Bureau of Tests and Specifications, giving the daily status of every job. This makes it possible to visit jobs which may be in particular need of such visits.

**Inspection of Highway Materials.**—All materials used for coarse aggregates are inspected after arrival on the job by the resident engineer and tests are made by his inspector. We feel that the man who is capable of passing on the placing of the concrete is equally qualified to accept or reject the materials going into it. The Bureau of Tests and Specifications furnishes complete field equipment for this purpose and when necessary carefully instructs the inspector in proper methods.

In case of dispute over the quality of concrete aggregates or at the request of the resident engineer a representative of the bureau makes a field inspection and if necessary brings samples to the laboratory for final tests and a decision is rendered by the chief engineer of the Bureau of Tests and Specifications.

Cement is tested under contract by commercial testing laboratories and loaded from bins and each car tagged with a county label. We have found this to be cheaper and more satisfactory than handling the cement testing by our own forces, but it is the only material not tested by our bureau.

Trucks from the Bureau of Tests and Specifications are driven by material testers and they visit the jobs at least once each week and in addition to an inspection of general conditions they obtain samples of cement, sand and aggregate which are taken to the laboratory for complete tests.

The resident engineer and inspector make concrete cylinders daily which are stored in the field and picked up by the bureau trucks for crushing tests in the laboratory. In addition to these daily tests the resident engineer also

prepares beams for testing concrete at important intersections. Beam testing machines are furnished in the field by the Bureau of Tests and Specifications and a representative witnesses the breaking tests of such beams in the field and the time of opening a road is authorized by the joint approval of the chief engineers of the bureaus interested.

We endeavor to test as many materials at the source of supply and in the field as possible, reserving the laboratory for chemical and physical tests which require special equipment and trained chemists and laboratory operators—we keep in mind the idea of having bureau representatives available for service in the field either in matters requiring special investigation, controversies in case of dispute, or assisting in the instruction given to new assistant engineers and inspectors.

**Inspection of Paint.**—All paint used by the county is purchased under rigid specifications and a chemist is sent to the plant of the paint manufacturer to test all materials before mixing. He sees that the proper proportions are mixed and ground together, and the finished paint is weighed into containers and sealed in the presence of an inspector. The method of purchasing paint under specifications has not only enabled us to obtain a much better paint but has resulted in a saving of $8,000 per annum in comparison with purchasing prepared paints.

**Wire Rope for Barriers.**—The specifications for heavy wire rope for safety barriers require a minimum weight of coating of not less than .8 of an ounce per square foot in addition to the usual Preece Test. These materials are sampled at the warehouse or plant of the producer and each reel sealed before it is released for delivery to the contractor or county maintenance division. The same method is used for the inspection of all other fixtures used in barrier construction, and unless the materials arrive on the job sealed by the bureau's official stamp the inspector in the field will not accept them.

**Asphaltic Concrete.**—Before starting the construction of an asphaltic concrete wearing surface a material tester goes to the plant with a box full of equipment and all mineral aggregates are tested. Asphalt cement is brought to the laboratory for test and from the data obtained at the plant the proper proportions are prescribed by the asphalt technologist in the laboratory and when the plant is ready to start, the inspector at the plant sees that the proper weights are used. A loading ticket is delivered to each driver, giving the temperature and weight of the material of the truck. Daily samples of the finished concrete are taken in the field and sent to the laboratory for extraction and test.

We found that our bituminous extraction on coarse asphaltic concrete did not check with the amount of material known to be weighed in at the plant on account of the difficulty in obtaining representative samples within the capacity of the extractors. Since mortar has about forty times as much superficial area as a stone of equal volume the balance must be very nicely maintained. Some method of correction was necessary so curves showing the relationship between the weight and area for the different sieve sizes were developed. The details of the method have been published in Circular 49 of the Asphalt Association, 1927. Briefly the total superficial area of the aggregate actually extracted is found from the curves and multiplied by the amount of bitumen required per unit area by the specifications. This figure is directly comparable with the bitumen found by extraction without fear of error due to sampling. Such corrections are necessary when check tests are made for percentage of bitumen used in coarse aggregate mixes.

**Co-operation Necessary to Enforce Specifications.**—Without the co-operation of every man in the construction bureaus from top to bottom the Bureau of Tests and Specifications would have a hard time. One way of obtaining such co-operation is to keep constantly pointing out horrible examples of bad construction both at home and abroad and insisting that—"the best is not good enough."

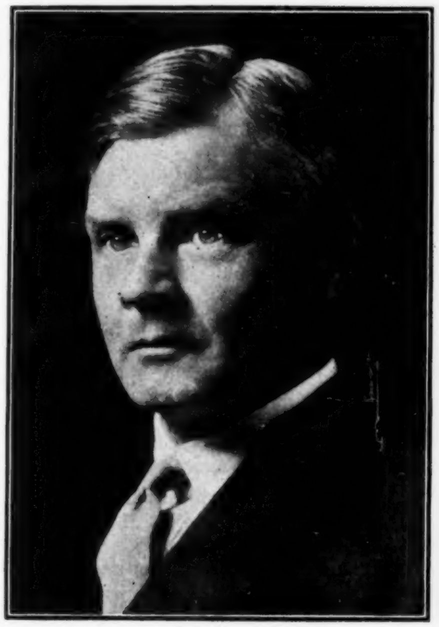
It has been found worth while to make inspection trips to point out failures due to unsound aggregate, lean mix and poor design and construction in bridges and roads. It is surprising to find how many engineers have not observed the failures which are taking place in roads and structures all around them. In general, it is easier to notice failures in highways than in masonry, but when an engineer once becomes critical and realizes that the structures which he has been building are not permanent he will then be ready and willing to co-operate with a testing department to the fullest extent in order to eliminate that one variable of inferior materials from the many which enter into modern highway construction and thereby becomes a loyal supporter of the Bureau of Tests.

**Acknowledgment.**—The foregoing is a paper presented Feb. 21 at the 15th annual conference on Highway Engineering, University of Michigan.

## Federal Road Engineer Is Loaned to Colombia

Edwin W. James, chief of the Division of Design of the Bureau of Public Roads, U. S. Department of Agriculture, has been appointed by the government of Colombia to serve as a member of a commission to study and prepare plans for the improvement of the entire system of transportation and communication in that country.

At the request of Dr. Enrique Olaya, the Colombian Minister at Washington, Mr. James has been relieved of his duties in the Federal bureau for a period of three to six months. He sailed from New York on March 21 to take up his new duties at Bogota.



Edwin W. James

The commission, known as the Consejo de Vias Comunicaciones, will consist of five members, three of whom will be foreign engineers, selected as expert advisors on highway, railway and waterway transportation. Mr. James has been appointed as the highway expert.

The request for Mr. James' services follows widespread interest in South America and Central America aroused by repeated suggestions in this country that the United States extend aid to the Latin Republics in matters of road improvement by the loan of trained engineers as advisors.

Mr. James has a wide knowledge of all phases of highway engineering problems. His recent book entitled "Highway Construction, Administration, and Finance," has been translated into Spanish and has enjoyed a wide circulation in Central and South America as well as in this country. He is the author of numerous papers and technical treatises on highway engineering.

Mr. James has served with the Bureau of Public Roads since 1910. He was technical advisor to the American delegation to the International Trade Conference on Automobile Traffic in Paris in 1926, and secretary of the Joint Board of Federal and State Highway Officials which planned and arranged for the marking of the United States highway system. He is a graduate of Harvard University and the Massachusetts Institute of Technology, and is a member of the American Society of Civil Engineers, the American Association of State Highway Officials, and other engineering societies.

# Construction of Crushed Stone, Gravel and Shale Roads

## Present Practice in Wisconsin

By T. M. REYNOLDS
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AS long as anyone of us is connected with the road building industry, either on the planning or on the actual construction end, we will be called upon to design and construct many miles of crushed stone, crushed gravel and shale roads. These higher type of surfacings will always form the background of our road system in the rural communities. They will be found to constitute the largest mileage of our surfaced highways, because it is impossible to finance and unwarranted economically to build higher type or so-called hard surfaced roads on our lighter traffic roads, most of which will never have a traffic count of 750 vehicles per day. It therefore behooves all of us to continue our study of the lighter type of surfacings and aim to develop new economical methods of construction and maintenance.

**Availability of Material Deciding Factor.**—The deciding factor in the choice of stone, gravel or shale is the availability of the material locally and the cost of it. There exist in Wisconsin considerable areas in which only one of these three types is available at a reasonable expenditure. In every case, the cost of locally produced and shipped in material is checked, for we desire to secure the most suitable as well as the most economical surfacing material. The material in use is classed as Trenton, Galena or Lower Magnesial limestones, granites, quartzites as found in the Baraboo territory; gravels which are found in eskers, terminal moraines and outwash deposits; and Franconian, St. Lawrence or Eau Claire shales. The Franconian and St. Lawrence shales are more stony than the Eau Claire shale, which usually has a high clay content and becomes very slippery in wet spells.

**Investigation of Material Sites.**—The next step is to make a careful investigation of the region for possible sites from a standpoint of development, quantity of material available and accessibility to the proposed work. The promising sites are thoroughly test pitted. The test pitting operation then gives us an adequate idea of the amount of stripping, uniformity and quality of the deposit and its depth. In the case of limestone and shale formation, four to six tests pits per acre may suffice. For gravel, test pits should be sunk approximately every 50 ft. and sample taken for every 3 ft. of depth so that screen analysis can be made. In stone or shale deposits which have already been opened, it is still necessary to test pit, for although the deposit will have the general appearance of being satisfactory, there is a possibility that sufficient material is not there or the stripping would make the site an expensive one to develop further.

The material sites are purchased by the state or county at a price of ¼ ct. to 10 ct. per cubic yard, which also includes the necessary access to the site from the public highway. General practice is to buy on an acreage basis rather than a cubic yard basis. Sufficient acreage is bought so that additional material can be taken out when needed for maintenance work.

**General Construction Features.**—In design the shoulder to shoulder width of the roadway is usually 26 ft. and the material is featheredged over this width. When sandy subgrades are encountered, it is necessary to add clay or other suitable top dressing to the subgrade before a crushed stone or gravel surfacing is applied. Some gravels have sufficient binder so this top dressing is not required. In the case of gravel and crushed stone roads, the rate of application is 1,500 to 2,000 cu. yd. to the mile. The material is placed at least in two courses, with the first or base course covering 22 ft. of the 26-ft. top. The top course then is spread over the base and featheredged so the entire width is covered. The base course is started at the point nearest the source of supply and is placed over the entire length of the project before starting the top course. However, in cases of wet subgrade, the contractor is permitted to start the top course. With shale surfacing, the practice used to be to build it 18 ft. wide and 9 in. loose depth. In the last two years several projects have been built using the featheredge design. Although this type requires about 20 per cent more material, the results secured have been worth it. Shale is applied at the rate of 2,500 cu. yd. to the mile.

**Sizes of Materials.**—The past few years have seen a gradual reduction in the sizes of the various materials used in these types of surfacing. Where we formerly permitted a 1½-in. size in crushed stone and gravel, we have, in 1928, used material passing a 1-in. circular opening. However, with the use of pea gravel ranging from ¼ to ½ in. in size in some portions of the state, which produced a better travellable surface and one easier to maintain, we have decided to produce stone and gravel passing a ¾-in. circular opening in 1929.

The size of the shale used has been reduced from an 8-in. size to 4 in. On one project on a county trunk in Vernon County, the shale has been passed through a jaw crusher so as to produce a 2 to 3-in. size. This project was completed late last fall, so no results are available at this time. However, as shale has been generally hand broken, we believe that the expense of crushing will be less than that of breaking by hand. It is more difficult to keep men at work breaking the shale. The size of the shale as incorporated into the road is no doubt more uniform when crushed.

The first step towards producing material, after the site is picked, should be the development of a carefully thought out plan for the required equipment and its arrangement in the pit or quarry. The quantity of rock, gravel or shale to be produced daily in order to finish the work within the number of working days allowed, is a vital factor in deciding upon the size of the equipment and its arrangement. The equipment selected should have some reserve power and capacity, for it will not result in as much wear and tear on the machinery as if it does not have to be crowded all the time. The quarry site or gravel deposit must be thoroughly stripped over a sufficient area so that delays will not be experienced when the work gets under way.

**Crushed Stone Production Methods.**—The methods of getting rock or gravel to the crusher vary considerably. Hand loading of the quarried rock is still used quite a bit but power shovels are rapidly displacing the man power. When there are considerable clay seams in rock deposits, one will have to watch power loading for the shovel will pick up more clay fines which will be included in the final product. Too much of the clay will produce a slippery road in wet weather.

There is a wide assortment of crushing equipment in rock quarries. We have had single crusher units, a primary and secondary crusher and a primary crusher and rolls. The screening equipment has been of the rotary and shaker types.

The production per actual working day of 10 hours on six fine crushed stone projects has varied from 75 to 127 cu. yd. with an average of 96 cu. yd. per actual day worked. The number of cubic yards on these six projects varied from 7,293 to 24,434. The high average of 127 cu. yd. per actual 10-hour day worked was made by a single unit crusher and hand loading of quarried rock into trucks. The material was crushed to a size passing a 1-in. round opening.

**Work Carefully Planned.**—My conclusions on the production of these six projects are that on the 127 cu. yd. job, the work had been carefully planned and the crew was efficiently trained and the work completed within five days of the allotted time. After deducting delays due to bad weather, the production for the period from the start of the crushing operation to the finish has only averaged 72 cu. yd. based on a 10-hour day. My experience is that more careful planning and management is necessary on the crushed rock jobs in order that the jobs will be finished within the number of working days allowed. After the trucks have hauled the finished product to the road and dumped their load, it is spread out to the required width with a light two-horse grader.

**Spreading Crushed Rock.**—In spreading crushed rock, the operator of the grader should go to the bottom of the material dumped on the road and spread all material over the road in order that it be thoroughly mixed. We have found it a good practice not to dump the rock the full depth of each course at one time but to spread each load as long a distance as it will spread readily and repeat this operation until the desired depth is secured. This method makes it easier to spread smoothly and eliminates the chance of getting a load of fines all dumped in one place. In all cases fine crushed rock should be placed in courses of not over 4 in. and preferably 3 in. in order to get good compaction and a better distribution of material. The small grader outfit also helps to keep the subgrade in good condition just ahead of the base course. As the fine crushed stone or gravel surfacings are traffic bound, a motor propelled grader with at least a 10-ft. blade maintains the surfacing until it is accepted. Where breaks or weak spots occur, additional material is placed. In some instances, it is necessary to dig out the spongy spots and backfill with a more suitable soil.

The cost of the traffic bound fine crushed stone roads has run from $1.93 to $2.50 per cubic yard incorporated into the road. On the basis of 2,000 cu. yd. to the mile, the cost per mile has been $3,800 to $5,000.

**Shale Production.**—In the shale work, more attention must be given to the stripping of the overburden. Small power shovels are doing the loading in the pit in place of hand labor. With power loading, there is a tendency not to break up the shale in the pit to the size required. Through power loading and the use of motor trucks or hauling, the amount of shale placed on the road has increased at least 100 per cent. With the thin bedded shale and power loading, as high as 500 cu. yd. have been placed in 10 hours. However, the production on four jobs has varied from 177 cu. yd. to 344 cu. yd. in a 10-hour day and the average is 235 cu. yd. per working day.

**Shale Road Construction Features.**—Shale is spread on the subgrade the full thickness for a width of 20 ft. Any large size pieces which have not been broken up in the pit are broken up by men at the dump. A light grader is used to spread the shale. Where the road is open to traffic, the finishing operations must be right behind the freshly dumped material.

In finishing the road for traffic, a 10-ton tractor, a heavy 12-ft. blade grader, 5-ton roller and a long planer are used. The roller is operated on the edges first and works towards the center. Immediately following the roller, the 12-ft. blade grader is used with the blade set at right angles to the centerline and at a cutting depth so that the mold board is full. This step is vital in producing a smooth riding surface. Further rolling is done and the blade kept in operation until the road surface is compacted and a smooth even riding surface has been produced. Often times a long heavy road planer has to be used to secure the desired surface in addition to the grader.

On certain types of thin bedded shales the roller can be dispensed with and the shale is traffic bound, being kept smooth at all times with the heavy 12-ft. blade grader and planers.

With the use of trucks for hauling shale we have practically abandoned the winter productions. Further, shale spread in the winter time on a frozen grade turns out to be a hindrance to travel in the spring months and is not spread uniformly because it is almost impossible to clear off all snow and ice before depositing the shale.

**Shale Base; Gravel Surface.**—While a good many projects have been built with nothing but shale surfacing due to limited funds, we now believe this practice should be eliminated on our main highways. In its place the shale should be considered as a base course. The top or wearing course should then consist of 200 cu. yd. per mile of pea gravel. An additional 100 cu. yd. per mile should be stock piled and added to the road surface as bare spots show up. Any heavier application of road metal will be too loose on the surface and will make driving dangerous. Knowing the geological formation adjacent to the proposed project, one is able to make a decision readily as to what type of material is apt to be available for the surfacing.

Where a pea gravel surfacing is to be added as a wearing surface to a shale base, we are running a disc harrow over the compacted surface to slightly loosen it. This helps in securing the penetration of the pea gravel into the top of the shale and the loose pea gravel compacts more readily.

Shale has cost us $0.90 to $1.40 per cubic yard with average hauls varying from 1½ to 4 miles. At 2,500 cu. yd. to the mile the cost is $2,250 to $3,500. If 300 cu. yd. of pea gravel are added to the mile, the aforementioned figures will have to be increased $600 to $900 per mile.

**Gravel Production.**—Gravel materials are usually brought to the crusher and screening plant with the aid of drag lines.

The average production per 10-hour working day is 225 cu. yd.

The method of spreading is practically the same as mentioned above for crushed stone roads. The material is traffic bound. In the cases of sandy gravels, it is sometimes found necessary to add a small percentage of clay to facilitate the setting up of the gravel. A motor grader is kept at work on the surface and this is supplemented with a heavy tractor drawn grader when necessary.

Crushed gravel has varied from $1.25 to $2 per cubic yard and at the rate of 2,000 cu. yd. to the mile the per mile cost is $2,500 to $4,000.

From a standpoint of traffic service, the fine crushed stones, gravels, and gravel on shale base are giving excellent results for the amount of money expended. During the spring break-up and prolonged wet spells we will have to expect bad breaks in the surface. We have found, however, that there has been a marked increase in traffic wherever a large mileage of this type has replaced the earth road. As a result, dust layers have had to be used and gradually these roads are assuming a bituminous character. The time is now here when the bituminous surface treatment will have to be made a part of the original construction, although the application of such a binder would not take place until the surface has passed through at least one winter. In other words, the initial improvement of our lighter type of surfacings with bituminous materials is not a maintenance operation but a construction operation.

In closing, I desire to state that in order to maintain a satisfactory rate of production for the number of working days allowed, more advance thought and efficient planning is necessary, so that when work is started, the plant layout and its management will operate efficiently.

**Acknowledgment.**—The foregoing paper was presented at the 18th Annual Road School of the Wisconsin Highway Commission.

# The Engineer's View of the Contractor

## With Especial Reference to Highway Construction in Iowa

By ANSON MARSTON

Dean of Engineering, Iowa State College, President, American Society of Civil Engineers

THE title assigned by the program committee for this paper is quite appropriate. It suggests that the relation of the engineer to the contractor is that of a man to a man, as contrasted with the relation of a representative of a profession to an agent of a business organization. The true relation has always been that of man to man.

**When the Relations Were More Primitive.**—Forty years ago when the speaker was serving his engineering apprenticeship as a raw college cub, not long from the farm, the relation of the engineer to the contractor was considerably more primitive than now. The writer's apprenticeship was in railway and bridge location and construction in the middle west and in the south, successively as rear flagman on location, rodman and then resident engineer on construction, transitman and then chief of party on location, and finally resident engineer on steel bridge construction, all within six years.

When the writer began his apprenticeship he was so ignorant of the relations then prevailing between engineers and contractors that he went without his dinner and almost without his supper his first day on railway construction in the immediate vicinity of a contractor's camp. Before his apprenticeship days were half over he became so enlightened that one stormy night in Louisiana, many swamp wilderness miles from residency headquarters, he acquired an extremely undesirable alien population from a contractor's blankets.

During his apprenticeship the speaker held many and different ideas of different contractors, varying from implicit trust to unconquerable suspicion. He has often wondered what were the contractors' ideas of him. He realizes, and dimly realized then, that his blunders due to lack of experience must often have been crosses and may sometimes have caused losses, but he still hopes that most of the contractors whose work he directed believed in his fairness of intention, in his honesty, and in his determination to secure good work, and that they respected him in due moderation as an engineer. The speaker still believes that the contractor whose slope stakes for a large fill he set out where they belonged after they had been moved in a couple of feet, liked him all the better, and that the contractors of those days had no real use for a weak, incompetent or unscrupulous engineer, even when they owned him.

**Few College Trained Engineers Then.**—In those days only a negligible proportion of the railway engineers with whom the speaker came in contact had received any college engineering training. In spite of the existence of some technical engineering societies, engineering was not recognized or organized as a true profession comparable in professional requirements and standing with medicine or law. In those days there was no organization of contractors comparable in any way with the Associated General Contractors. The writer recalls at this time only two contractors among all those whom he met in six years who were themselves engineers, nor did he expect ever to address an audience of contractors like this, of whom a large proportion are entitled to wear the badge of at least one of our greatest national engineering societies.

Cut Through Clay at Honey Creek Hill on U. S. Highway 30 in Pottawattomie County, Iowa

The Engineer's ideas of contracting and contractors have necessarily been modified by the great progress in engineering and in contracting which has been made in the last 40 years. Engineering is now really organized and really recognized as a true profession, with ever higher standards for membership. The codes of ethics of the principal national, state and local engineering societies are enforced with increasing strictness. One occasionally is forced to grieve over the humiliation of an old time engineer or engineer-contractor, disciplined for practices for which he is worthy of blame only in the same degree as is the old dog who is shot because he learned to suck eggs when a pup and knows no better.

The engineer registration laws already in force in 24 states seem sure to be extended to many other states, and to be enforced with increasingly severe examination requirements and increasing attention to engineering ethics, so as to secure higher and higher qualifications of engineer practitioners. Such laws must not be judged by their present imperfections and impotences. Remember that the grandfather clauses will in due time become inoperative for lack of grandfathers.

The speaker does not claim that all engineers are now highly qualified professional men, or that engineers willl ever become infallible, but he does believe that engineers are now worthy and are becoming more worthy of a much increased and increasing degree of trust and responsibility in the awarding and the execution of contracts for works and operations.

The views which the speaker is about to express on the subject of the award and execution of public contracts have been formed mainly as the result of his 23 years' experience as the ex officio member of the Iowa State Highway Commission, from which service he

asked and received release in 1927. The Iowa State Highway Commission was originally located by law at the Iowa State College and occupied quarters in the engineering buildings. It is still located in the college town, over 30 miles from the state capitol.

**Only Two Chief Engineers in 25 Years.**—The commission has always functioned mainly through a carefully built up engineering organization, composed of engineers appointed, paid, promoted and retained in office entirely on a merit basis, eliminating politics entirely. The commissioners themselves receive only a nominal per diem remuneration, and they function like a board of directors of a railway. During the entire 25 years since its origin the commission has employed only two chief engineers, the second promoted from the organization for merit when the first resigned to become Chief of the U. S. Bureau of Public Roads. From 1913, when the commission was first given extensive authority, to 1927 only two permanent changes were made in the commission's membership, one by death and the other by voluntary resignation for business reasons.

The Commission employs several hundred engineers, the number increasing and decreasing during each year and from year to year with the actual needs of the work. All the engineer employees in the more responsible positions have had many years of highway engineering experience.

**$120,000,000 Expended on State Road Construction.**—The magnitude of the public works constructed by the Commission may be judged by a few statistics of their cost:

1919-1929

State road construction.... $120,000,000
(In 1928—$30,000,000)
State road maintenance.... 15,000,000

Estimated 1929-1935

State road construction.... $120,000,000
State road maintenance.... 19,000,000

The above is in addition to the preparation of standard plans and specifications and many detailed plans, and the approval of all important contracts for all permanent construction on county roads, costing many millions of dollars.

The commission has its own adequate and competent accounting force. All construction bills require the approval of a resident and then a district engineer, careful audit by the commission, and a formal audit by the state; after which they are paid by the State Treasurer directly from the State Treasury. The system is so efficient that although the work is scattered over 56,000 square miles bills are usually paid within ten days of their dates.

Once every year all the accounts and expenditures of the commission are thoroughly checked by expert accountants from the state budget department. This practice started upon the voluntary request of the commission, but upon its recommendation is now required by law.

During its entire history the commission has been constantly subject to bitter political attack, but never during its entire history has the slightest attack been upon the commission on account of any charges of graft or of favoritism in awarding contracts.

These are the conditions which must be kept clearly in mind in connection with what is now to be said about the methods which have been used successfully in awarding contracts for the great volume of construction work described, plus a large amount of maintenance equipment.

**Work Done by Contract.**—Substantially all the commission's construction work has been done by contractors holding contracts awarded after receiving open competitive bids. In 1920, when contract prices were running wild, the commission experimented to a limited degree with the day labor plan, but found it to cost more than contract work. Contracting is an intricate business, almost a profession, for which even a state highway commission with a great organization is not properly prepared and equipped. The Iowa State Highway Commission has saved Iowa many millions of dollars by keeping out of the contracting business.

The plans and specifications, and contract forms for the commission's contracts are very carefully prepared. The survey data are complete, and often cover several alternate plans. The design force is competent and experienced and prepares its designs in full detail with careful study. The specifications are mostly standard specifications, developed by long experience to cover clearly every phase of the work. These specifications are revised yearly. Frequently the contractors are invited into conference while the annual changes are under consideration, and thorough joint study is given to the various clauses and their correct interpretation. Effort is made in preparing the specifications to avoid necessity for "extras" not priced in the bids by classifications of material clauses and other provisions to cover all contingencies likely to arise.

Bids are opened and read in the presence of the Commission at public lettings, and are then studied and compared in detail by the proper engineer employees, upon whose final recommendations the awards are made.

**Latitude in Awarding Contracts.**—By reason of its long successful experience and the public confidence built up on the Commission's record, the Iowa laws governing State Highway Commission contracts have been developed to give the Commission a considerable degree of latitude in awarding contracts to other than the lowest bidder whenever the best interests of the state require. Section 4755-b11 of the Code of Iowa reads as follows:

"In the award of contracts due consideration shall be given not only to prices bid but, also to the mechanical and other equipment and the financial responsibility of the bidder and his ability and experience in the performance of like of similar contracts."

Earnest effort is made to award each contract to the very best interests of the state. When all bidders are properly qualified to perform the obligations of the contract it gives without question to the lowest bidder.

The commission does not feel that it can wisely refuse to award a contract to a properly qualified bidder merely because his bid is too low to enable him to earn some profit with good management. Such bids, however, are not desired for it is realized that to get the best results a corps of contractors

Forest Hill Bridge, 24 ft. Roadway, 240 ft. Span, on U. S. Highway 65 in Hardin County, Iowa

must be available who have been trained by experience in the particular kind of construction to be contracted, and that the services of a contractor so trained are a valuable asset to the state which will be lost if the contractor goes bankrupt.

**Pre-Qualification Requirements.**—The commission exercises much care and freely uses its discretion in its prequalification requirements of contractors. They must show financial ability to meet all their contract obligations, including quick and total really available assets of amounts satisfactory in proportion to their total obligations. New bidders must present definite convincing proof of their contracting accomplishment elsewhere and their ability to deliver satisfactory performance of contract. Even then they are ineligible to a first contract for more than 12 miles of road. Former successful bidders who have not done good work with reasonable promptness are shut out from new contracts. Contractors already overloaded with uncompleted contracts are refused additional contracts until their performance overtakes their obligations on present contracts.

Strict compliance during construction with the contract plans and specifications is an absolutely essential feature of correct relations between engineers and contractors. Otherwise, bidders cannot know on what they are really bidding. The speaker submits the thought that other contractors ought to enter complaint when they see the successful bidder for any contract getting away with noncompliance with the plans and specifications on which he bid. Thereby he and the engineers over him are injuring the contractors who bid for the same work in good faith.

The contract plans and specifications should be so carefully and thoroughly prepared by the engineer as to cover every feature of the work in the clearest manner practicable, treating each item or feature completely, in one place only. Plans and specifications which are not complete, definite, just and clear mean added cost to owners in the long run.

**Materials and Workmanship.**—The engineer should never specify both the results to be secured and the materials and workmanship. In general, he should specify the materials and workmanship, leaving the responsibility for results upon the owner and staking his own professional reputation on the outcome.

To illustrate what is meant, mention will be made of an occurrence which is very common in sewer construction at the present time. It is absolutely unjust to hold a sewer contractor responsible for the cracking of sewer pipe due to overloads from ditch filling materials when he has supplied sewer pipe which meet fully the requirements in the plans and specifications and when he has laid the pipe in compliance with the plans and specifications.


**The Correctionville Bridge on Road 20, Woodbury County, Iowa; Three 90 by 20 ft. Deck Girders and Two 50 ft. Approaches**

Guaranty clauses in contracts, such as those requiring paving contractors to guarantee paving for a term of years, are unjust to the contractor and expensive to the public. Their only justification is incompetent or corrupt engineering, the proper remedy for which is to find competent and reliable engineers.

**Surety Bonds.**—On construction work of the magnitude of that of the Iowa State Highway Commission, the cost of surety bonds becomes an important matter. Since the contractor must include the cost of such bonds in his prices bid, the surety bonds for the $30,000,000 of construction on Iowa state roads in 1928 cost the state $450,000 for the rate charged was 1½ per cent. Surety bonds for the $120,000,000 construction program which has been laid out for the next six years will cost Iowa $1,800,000, yet the state has recovered from surety bondsmen on state road contracts only an insignificant amount in the last ten years.

The speaker does not claim or believe that it is safe in general at the present time to release awards of contracts for municipal and state public work from definite and fairly strict legal limitations. There are too many and too notorious instances of political favoritism and graft to justify wide latitude, except where a strong, permanent and thoroughly competent and reliable engineering organization has been built up during years of service so meritorious as firmly to establish a merited and lasting public confidence.

The ideal method of awarding contracts no doubt would be for a thoroughly competent and reliable engineer or group of engineers, with comprehensive, definite and clear plans and specifications of the works on a table before them, to call in a sufficient number of competent, reliable and financially responsible contractors, go over the work with them in complete detail, and after a time sufficient for each contractor to submit a carefully prepared bid award the contract to the best interests of the owner.

**Ideal Conditions of Award.**—In practice, public work must usually be advertised, calling for sealed bids to be opened in public, with legal limitations on freedom to award. To permit as near an approach as practicable to the ideal conditions of award two things are essential:

First, thoroughly competent and reliable engineers, upon whom the public can and does not rely.

Second, thoroughly competent, reliable and responsible contractors, whom the engineers and the public can trust and do trust.

Here is where a powerful national and state organization of contractors, like the Associated General Contractors, can render indispensable service both to the contracting industry and to the public. The untrustworthy, incompetent and irresponsible contractor should be distrusted and barred, and expelled upon occasion, by the organization which is representative of contractors.

In conclusion, the engineer's view of the untrustworthy, incompetent, irresponsible contractor is the same as his view of the untrustworthy, incompetent engineer. Both should be barred from the callings which they disgrace.

The engineer's view of the trustworthy, competent and responsible contractor is that he is a worthy brother and an essential co-worker in a great calling, an agent indispensable to civilization.

The engineer's view of the properly qualified contractor is best evidenced

A View on U. S. Highway 218 in Benton County, Iowa

by the large and increasing number of contractors who are admitted to honored membership in our greatest engineering societies. Your secretary has just completed three years' service as a director of the American Society of Civil Engineers. The secretary of your Iowa branch serves on the Iowa membership committee of the American Society of Civil Engineers.

Engineering colleges are enlarging the special training which they offer their students in the elementary principles of contracting, and they take keen pride in the achievements of their alummi engineer-contractors.

More and more the engineer's view, which perhaps you may resent, is coming to be that the contractor, after all is said, is just a brother engineer.

**Acknowledgement.**—The foregoing paper was presented Feb. 20 at the annual convention of the Associated General Contractors of America.

## 2-Course Concrete Pavement

By THERON M. RIPLEY
Chief Engineer, Greater Motorways System, Erie County, New York

During the past few years the study for design of concrete pavements has brought more into favor what is known as the two-course pavement.

In the original concrete pavement design the full thickness of the pavement was built in one operation of the same constituency of mix, and in a great majority of cases a much larger proportion of 2 in. and 3 in. stone was required than that of a smaller size. In some instances specifications excluded the smaller size, namely No. 1 or pea gravel, or the assumption that a stronger pavement was thereby secured.

The exclusion of this smaller part of the coarse aggregate worked a great hardship upon many producers as the bulk of their coarse aggregate was of the finer grade, suitable for the thin walls, pilasters, etc., but being excluded from the great and growing use in highway construction.

Several years ago the County Engineer of the County of Erie, Mr. George C. Diehl, began building a two-course concrete pavement. The first of these pavements in Erie County, exclusive of experimental pieces, was laid in 1925, when 94,809 sq. yd. were put down. From 1925 to 1928 inclusive, there has been laid, 98.52 miles, equal to 1,021,724 sq. yd. by the County of Erie, and during the years 1927 and 1928 the State of New York laid in its western division of which Erie County is a part, 33.70 miles, equal to 418,507 sq. yd. Moreover, the towns and villages in Erie County have laid this pavement with the result that nearly 2,000,000 sq. yd. have been laid in the Buffalo-Erie County district. What makes this of peculiar interest to the gravel producer is the fact that the top course of this pavement uses as its aggregate the No. 1 or pea gravel, exclusive of the large sizes.

In the early years of this work it was at first difficult to convince contractors that there was not a material increase in cost of doing the work by the two-course method over the one-course method. The steel reinforcement in pavement has become a standard practice in all progressive states and the placing of this reinforcement was usually about 2 in. from the surface of the pavement, and moreover, as specifications required that the concrete should be screeded to the proper elevation for receiving the reinforcing material it was brought to the attention of complaining contractors that they were practically building a two-course pavement under the one-course specifications and that the only difference in the manipulation of the two classes of material was a little more thought exercised in delivering material to the mixture and in proportioning the same. As practically all concrete pavements were being laid from 6 to 8 in. thick it is readily seen that the No. 1 product under the two-course pavement design immediately obtained a monopoly on from 25 to 33⅓ per cent of the total pavement laid. This, in many cases immediately solved the problem of disposing of the entire product of the finer aggregate from many pits.

This two-course pavement was developed in an effort to secure a finished surface, free from checking and cracking. It has been successful under five years of trial. A further development of the two-course pavement is a recent patented adaptation known as "Sheet Concrete." We have laid some of this pavement in Erie County but its age is not great enough to yet predict any definite statement of permanency therefrom.

Let us see what the use of two-course in place of one-course concrete pavement would mean, to the producer of No. 1 stone or pea gravel.

*Assuming the one course to be 1:1½:3 mix using run of crusher (exclusive of sand below ¼ in. and No. 1 stone in excess of 25 per cent of the coarse aggregate) and assuming the two-course pavement to have a bottom course two-thirds the thickness of the pavement and 1:2:4 mix, the top course one-third the pavement thickness and mixed 1:1:2 using only No. 1 for coarse aggregate; then:—

The one-course pavement could contain not to exceed 25 per cent No. 1 gravel. The two-course will contain 25 per cent of two-thirds equal to 16.6 per cent plus 100 per cent of one-third equal to 33.3 per cent or a total of 49.9 per cent; in other words, the use of two-course concrete pavement doubles the amount of No. 1's allowable in the mix.

The two-course concrete pavement for a number of years has been giving excellent satisfaction in Erie County, New York, in the Buffalo District and has within the last two years been incorporated in the New York State specifications and constructed as heretofore noted.

**Acknowledgment.**—The foregoing is an abstract of a paper presented Jan. 10 at the annual convention of the National Sand and Gravel Association.

*These mixes are here used for comparative purposes and should not be considered as applying to any particular job.

# Surface Treatment of Old Concrete Pavements

## Practice in Western Counties of New York State

By CHARLES R. WATERS
District Engineer, New York State Department of Public Works, Buffalo, N. Y.

THE first concrete pavement in New York State to receive a surface treatment, was that between Lockport and Olcott in Niagara County, in the western part of the state. After this road began to scale, studies of the conditions seemed to indicate that there was less scaling on the portion where oil had dropped from cars.

It was decided to give the entire surface of this road a treatment with bitumen in exactly the same manner as a macadam pavement is treated. This occurred in 1921 and since that time, surface treatments of various kinds have been given to other concrete pavements in the 5th district (Cattaraugus, Chautauqua, Erie and Niagara Counties) where I am located.

As an aid to clearness, I think we may describe the work of surface protection by dividing it into four parts, as follows:

- After scaling first appears
  - Traffic under 3,000 vehicles per 12-hour count
- Advanced stages
  - Traffic above 3,000 vehicles per 12-hour count
- Disintegration stages
- Patching

**Treatment When Scaling First Appears.**—When scaling first appears in isolated spots, 1, 2, 3 or 4 ft. in diameter, it is our practice to sweep the scaled area clean of dust and dirt and then paint the area with bitumen and blot it. For bitumen we use penetration grade asphalt, cut-back asphalts, emulsion and tars, hot or cold. The blotter is usually sand, slag or stone chips.

The supervision of the maintenance work in my district is divided into six sections and each maintenance engineer has about 175 miles of pavement to look after. On a broad basis, the engineers are instructed by the supervising engineer as to the type of bitumen to use for covering the scaled areas which appear first. However, the different engineers have somewhat different ideas, so that one may use bituminous penetration "A" for the bitumen, while another may use cut-backs or emulsion. There are certain advantages connected with each, and I cannot, at this time, express any great preference of one type of asphalt over another type of asphalt; nor a preference of asphalts over equivalent grades of tar products.

In general, the scaled areas are covered or patched at the same time that the cracks and joints are poured. As bituminous penetration "A" is customarily used for pouring cracks, the same material, taken from the same heating kettle in a simultaneous operation, is rather generally used to paint the scaled places.

The bituminous material is applied in a thin coat by means of hand pouring pots and push brooms or screeds. Sufficient cover is applied to blot the material and leave an excess to prevent traffic from disturbing the bitumen while it is setting.

The quantities used are about 0.20 gal. of bitumen and 10 lb. of cover per square yard. The cost is 10 to 12 ct. per square yard, depending on cost of materials, freight rates and length of truck haul.

The life of these patches is short, usually only a year or two, but I believe the work is very much worth while as it covers the open, porous spots and waterproofs them and retards the development of larger holes, and hence this treatment of scaled areas has a very beneficial effect on the life of the pavement.

In speaking of scaling, I do not mean a thin laitenance scale, which is common to the top of many structures, but a scale ¼ in. or more in depth.

A pavement which has begun to scale will ordinarily continue to do so. As the scaling continues to progress, a point is reached where it is no longer economical or desirable to cover the areas by the painting or swabbing method. Then we apply a complete surface treatment, either light or heavy, depending on the amount of travel and other factors.

Two-Course Concrete Pavement on Route 5 at Point where It Meets the City Line of Buffalo. This Is One of the Main Highways to the East from Buffalo and Carries 15,000 to 20,000 Vehicles Per Day. The Pavement Is 40 Ft. Wide Consisting of Four 10 Ft. Lanes of Concrete, and Is Built with Curbs and Sewers Similar to a City Street. There Is a 20 Ft. Trolley Area on the North Side of the Pavement. It is Expected This 20 Ft. Area Will Be Paved in the Near Future, Making the Total Width Between Curbs 60 Ft. The Road Leading to the Left Is for a New Subdivision. The Building of This Wide Pavement Has Increased Property Values Tremendously and Has Eliminated Traffic Delays. This Particular Project Was 3.13 Miles in Length and Cost $350,000

**Light Surface Treatment.**—For the ordinary light surface treatment where travel is not in excess of 3,000 vehicles per day, we use a cold application of tar, applying 0.25 gal. and blotting with 10 lb. of cover per square yard. For cover, we use coarse sand, pea gravel, No. 1 stone or slag. The tar is applied by means of a pressure distributor. We recommend tars for the first treatment, as we have found that tars are more penetrating than light asphaltic oils, especially if the surface contains a concrete dust that cannot be removed readily. The tars will penetrate through this dust and act as a priming coat for further surface treatments in succeeding years. The mat formed by this process is very thin. Ordinarily, the life of the surface treatment is short and only lasts a year or two.

Usually this light surface treatment is followed within a year or two with another surface treatment, using cut-

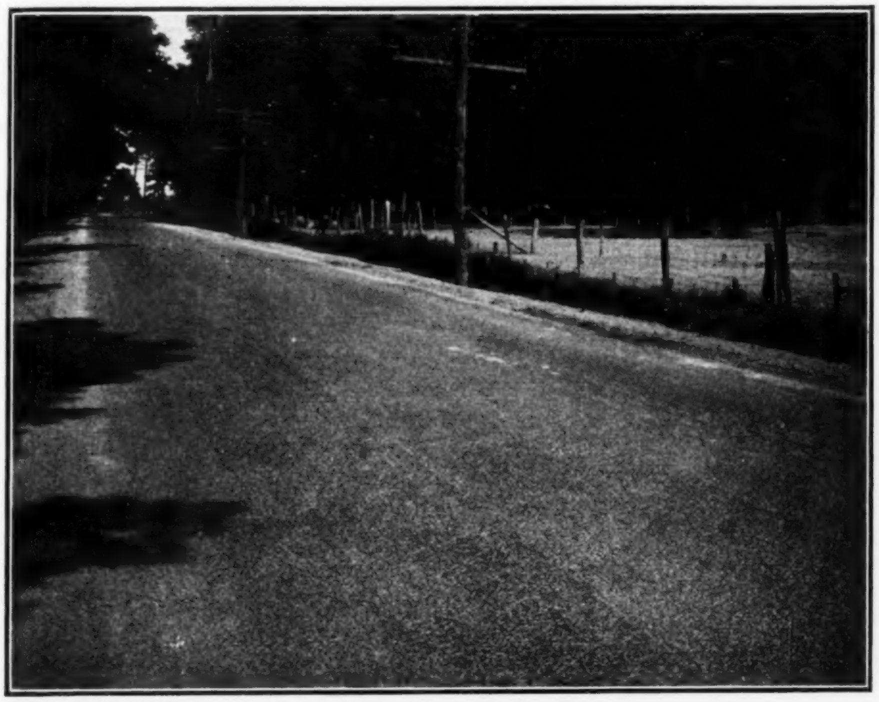
back asphalt or tar of the same consistency as cut-back asphalt, and applying ¼ to ⅓ gal. of bitumen and 12 to 15 lb. of cover per square yard. This builds up the mat slightly. In two or three years, further surface treatment will be necessary, depending on travel and other conditions. The cost of a light surface treatment is about $600 per mile for a pavement 16 feet in width.

In connection with the use of cold tars for the priming coat, I would say that we perform this work early in the year before traffic becomes heavy. Tar requires four to eight days to dry. Motorists object because it is so slow in drying and spatters on their cars when they drive over it. Even though only half of the road is oiled at a time, it is necessary to turn out and much damage is done to cars.

The asphalt cut-back used on the succeeding treatments, dries quickly and is not so objectionable from the motor owners' viewpoint. However, on account of lack of penetrative quality, cut-back asphalts are inferior to tars for the first or priming treatment.

**Heavy Surface Treatment.**—When the traffic count is over 3,000 vehicles per twelve hour count, we recommend the use of a heavy surface treatment. For this we used, until the 1928 season, either a penetration asphalt or tar of the consistency used for bituminous macadam work. This should be applied hot from mechanical distributors, using about ½ gal. of bitumen and 35 to 40 lb. of No. 2 and No. 1 slag, stone or gravel per square yard. After the No. 2 is placed, the No. 1 is applied and the entire surface is rolled with a heavy roller. In general, we have obtained by this method, a mat ¾ inch to 1 inch in depth and as a general proposition, a good riding road results. The cost of this heavy surface treatment varies from $1,000 to $1,200 per mile for a pavement 16 ft. in width.

This heavy treatment will hold better if the pavement has first received a priming surface treatment of tar. Ordinarily the heavy type will last two to four years, depending on the character of the traffic conditions of the old pavement and such factors. Whenever it shows signs of wear the treatment can be repeated, building the mat up further. If a road is in such condition that a heavy bituminous treatment has become necessary, it is essential that the black top surface be maintained. If it comes off, as it does from time to time, the uncovered area will ravel rapidly and dangerous holes develop in the pavement.



Asphaltic Cold Mixed, Asphaltic Concrete, 2 In. Thick Over Old Concrete Road in Erie County, New York

During 1928 we have been experimenting with a tar product of a consistency heavier than the tar used for cold applications but lighter than that used for penetration macadam. The results to date have been very satisfactory.

The use of hot, instead of cold materials, eliminates almost entirely, the objections which the motorists raise to our surface treatment (oiling) programs, and I am inclined to think that in the heavily traveled sections we will be forced to give up the use of the lighter tars and oils which do not become stable for several days after being applied.

One of the roads on which we used this type of hot tar was a road 7 miles long in Cattaraugus County. It was applied at the rate of ⅓ gal. per square yard and this was covered with No. 2 gravel, using about 100 tons per mile (width 16 ft.). Then, 100 tons per mile of No. 1 gravel was applied on top of the No. 2, and the entire surface thoroughly rolled with a 10-ton roller until a smooth surface was obtained.

After the treatment had been subjected to traffic for several weeks, it was found necessary to spread additional cover to take up the tar which bled through and picked up under steel tires and heavy truck traffic. We find that in all heavy surface treatment work, all the cover that the bitumen will hold, should be used.

It is interesting to note that the heavy tar on this project formed a perfect bond with the gravel and none of the cover has been disturbed or removed under traffic. As a result, we have a surface wearing mat approximately 1 in. in thickness over the entire pavement. The cost of this work for seven miles was $950 per mile, exclusive of overhead charges.

**Surface Treatment in Watertown District.**—The work of surface treating concrete roads is being performed in other districts in New York state. As an example of this class of work, and on account of the detailed information which it gives, I will read the following letter from County Assistant Engineer Lynch of the Watertown district in northern New York.

"In 1924, when road No. 5426, the concrete section of the Watertown-Adams highway, became badly worn and pitted to the depth of 1 in., we gave it an ordinary light surface treatment of T. C. A. and a coat of No. 1 stone rolled in, using approximately ¼ gal. per square yard and 50 tons of cover per mile of 16-ft. road.

"The object of the light surface treatment was to act as a priming coat which would serve as a base for the heavier tar material which was to follow.

"In 1925 we patched up the bare spots of this first priming coat and gave the road a heavy surface treatment of tar hot application of ½ gal. per square yard and a cover of 150 tons of No. 2 stone per mile of 16-ft. pavement rolled until the stone was matted. We followed this very closely as the tar warmed up and spread No. 1 stone into the melting tar in order to prevent it from coming up and flying in hair-like strings under traffic. This size will require 50 tons per mile extra stone.

"I wish to emphasize that this latter covering is very important, because if the bituminous material is not covered as it melts up through, the strings of this tar will get on to passing cars and subject the department to severe criticism because it is much harder to remove than the lighter material.

"This heavy surface treatment produced an excellent mat on the worn

concrete. In fact, many people thought it was a new road.

"After two years of heavy wear, the mat showed signs of wearing through, so we gave the road another heavy surface treatment of tar hot application, repeating the same process in 1925, taking care to follow up for two weeks afterward with No. 1 stone as the bituminous material melted through.

"The road is in first class condition at present and we are well satisfied with the results."

**Resurfacing.**—When a pavement has scaled to such a degree that the surface is almost completely gone and the remainder is beginning to disintegrate and ravel in spots, we have obtained very good results by various types of resurfacing. This is the kind of work which has actual stability, and is the ultimate treatment to be given all concrete pavements which are subject to disintegration from the various destructive agents. This type is a positive class of work, whereas the other surface treatments are simply temporary measures adopted for economical or other reasons for use until the resurfacing is necessary or as a holdover until funds are available to do a real job.

Under this heading, we have covered old concrete roads with the following materials:

2-in. to 3-in. bituminous tops, mixed cold, using cut-backs or emulsion.
Amiesite, tarvia-lithic.
Hot mixed modified topeka.
Resurfacing with concrete 5-in. and upward in depth.
Penetration macadam.

I think all the members of this conference are familiar with the resurfacing of the so-called "Syracuse Test Road." Someone has called this "second story" concrete. We have followed this scheme in covering three or four other pavements, but our minimum thickness has been 5 in. and probably nearer 6 in. I was somewhat skeptical as to this method in the beginning, but I am frank to say that the results in my district, using 5-in. and 6-in. depths, have been entirely satisfactory. The age on one of these is three years and another is two years. No cracks, to speak of, have developed and there does not appear to be any other unusual trouble. The cost runs up as the pavement alone amounts to about $30,000 per mile for two lanes. This method means a reconstruction job which is apt to cause greater delay to traffic than some bituminous type of resurfacing.

Reconstruction with a hot top modified topeka also interferes with traffic unless it can be laid half width at a time. It does not interfere with traffic as much as reconstruction with concrete, because vehicles can run on the new black top as soon as rolling is completed. In two cases, we built concrete curbing along the edge of the pavement, but on two or three other jobs we have placed the topeka without curbing or headers. There are many disadvantages to the use of curbing or headers and, personally, I am opposed to their use. The black tops, in all cases I have examined, have sufficient strength to maintain their stability without the curbs, whereas the curbs, in many cases, have held water which has disintegrated the asphalt and made patching necessary.

Amiesite or tarvia-lithic are purchased from manufacturers of these products. They are unloaded from cars and laid cold. We place these materials half width at a time and this causes very little interference with traffic.

One of our contractors set up a plant and mixed his own Type 4, which is similar to Amiesite. Another contractor is planning on doing the same thing. This may, in certain localities, materially affect the comparative prices on hot and cold asphalt surfaces.

One county assistant in my district reclaimed five miles of old concrete which was rapidly disintegrating, by covering it with a 2½-in. cold patch asphaltic emulsion top, which has now been in service five years. The subsequent maintenance costs have been practically negligible.

Many other stretches of roads have been covered with cold mixed bituminous tops, using cut-backs or emulsions. It has been necessary, generally, to apply a surface treatment to these tops the first year before winter sets in to keep the water out, but on the whole, this work has been fairly satisfactory when on a large scale, but I would not put it in the same class as the topeka or Amiestite tops. These various bituminous tops cost $10,000 to $15,000 per mile for resurfacing a pavement 16 ft. wide.

They present a surface practically impervious to water and being resilient and smooth, prevent impact stresses from being developed in the underlying concrete base. These factors seem to arrest practically all of the destructive agents which were at work on the uncovered pavements.

We have placed a penetration top on only one old concrete pavement, but I understand that some work of this character has been done in the central part of New York state.

**Light Surface Bituminous Treatment with Slag Cover in Cattaragus County, New York**

**Resurfacing with Amiesite.**—As an illustration of resurfacing with departmental forces, I wish to quote from a report of one of my assistants, the history of two roads in southern Cattaraugus County.

Road No. 5259, Salamanca-Little Valley scaled to such a degree that the surface of the pavement was almost completely gone, but the remainder of the pavement appeared otherwise sound and capable of carrying present traffic. The road was completed in 1913, gave evidence of scale in 1919 and 1920 and was surface treated in 1923, 1925 and 1927.

"To salvage this road, we widened the pavement from 16 ft. to 18 ft., widening on one side of the pavement with a slag course about 9 in. in depth when consolidated. Over the entire 18 ft. we put a 2½-in. course of Amiesite, laying one-half width of the pavement at a time in stretches of about 1,000 ft. The total cost of widening and placing the Amiesite was $17,000 per mile. This does not include overhead charges. Three miles of this road was completed

in 1927 and 1.25 miles was completed in 1928.

"Another illustration is a badly disintegrated old second class gravel concrete pavement. The road was accepted in 1914, but soon showed signs of weakness. It had been treated several times with light oils and at other times with light applications of heavier oils, until a mat of from ½ in. to 1 in. had been built up as a wearing surface. The original pavement had disintegrated until there was little evidence of bond in the concrete.

"In 1928 we widened the pavement from 16 ft. to 18 ft. (2 ft. on one side) with slag, approximately 9 in. deep when consolidated. Over the entire 18 ft., a slag base of No. 4 size was placed from 6 to 9 in. in depth. The variation in depth was necessary to eliminate excessive crown and to bring the surface to a smooth contour. Traffic was maintained at all times.

"Over the slag base, a top of 2½ in. of Amiesite was placed in two courses, one-half width at a time. Shoulders were then reconstructed and widened. In some instances, it was necessary to transport the dirt for shoulders a distance varying from ¼ to 1½ miles.

"The entire cost of the 1.6 miles of this work was $45,400, or an average of $28,000 per mile. This does not include rental of trucks, unloading equipment or depreciation of equipment.

"In this road we now have a road metal of 15 in. to 16 in. in depth, 18 ft. wide and of comparatively smooth surface. All of the work on the 1.6 miles was done by departmental forces and was completed between the first day of August and the 29th day of October."

**Patching.**—For patching, practically the same thing may be said as for resurfacing. That is, you may patch concrete with concrete or with some of the various types of bituminous tops.

Some of the county assistants in my territory have set up central mixing plants from which the ready-mixed bituminous materials are hauled to the job in trucks and placed at the point where needed. This is a much more economical method than the process more generally used of mixing the materials in a small mixer along the roadside. I would say the saving is as much as $2 per ton of mixed material and, in addition, much more can be accomplished in a working season.

The particular point that those not familiar with patching should observe, is to paint the edge of the patch, and unless the patch is placed in early summer and the bitumen has had a chance to work up, it should be surface treated, i. e., given a seal cost, if one expects to find it in place the next spring.

**Summary.**—To summarize, we paint with bituminous material the small scaled areas, as they develop. As scaling progresses, we apply a light surface treatment and prefer the use of tar for the first priming coat. Where the travel is heavy, we apply a surface treatment as soon as possible, building a mat about 1 in. thick. When this heavy treatment cannot be economically maintained we resurface, depending on conditions, with new concrete or with one of the various types of bituminous tops.

My general reaction to the bituminous type is that a thin cover is of assistance in delaying the disintegration but it is not the real solution. Our thick cold patch tops, 2½ in. to 3 in. thick, Amiesite, tarvia-lithic of the same thickness, hot mixed tops, either sheet asphalt or topeka, seem to be the most effective way of maintaining a satisfactory and adequate surface in those cases where the reconstruction work has not been delayed so long that the value of the old concrete, as a base, has been lost. Some of the old concrete roads were even less than 5 in. thick on the edges when originally built, and it is doubtful if they were ever thick enough, even in their original state, to support a bituminous top. In those cases, reconstruction with concrete is probably advisable.

**Acknowledgment.**—The above is an abstract of a paper presented at the 1929 convention of the Highway Officials of the North Atlantic States.

**Trans-Isthmian Highway, Panama.**—The Trans-Isthmian highway survey from France Field to the Alhajuela dam site has been completed. From the completed survey topographical maps will be made, from which the road and estimated cost will be determined. The surveyors under Mr. H. E. Merryman, will be transferred to Puerto Bello for a survey of the France Field-Puerto Bello road. The group under A. C. Snyder of the Pennsylvania State Highway Commission is already engaged on this survey, starting from the west end. The entire survey was scheduled to be completed before March 31, 1929.

**Construction of Montevideo-Colonia Highway, Uruguay, Authorized.**—The construction of the Montevideo-Colonia Highway was authorized Oct. 15, 1928. This highway is to be of concrete, six meters wide, and about 118 miles in length and together with several bituminous roads of access, will cost in excess of $7,210,000. Construction is scheduled to commence within the next six months, the work to be completed within three years.

**Miles of Motors.**—All motor vehicles licensed in Pennsylvania during 1928, placed end to end, would reach 4,875 miles the equivalent of an endless line from the Capitol to the Rose Bowl in Pasadena, Cali., and back again. Compared with the total improved mileage in the state, this gives each vehicle a cruising radius of less than a half-mile, although each is entitled to a quarter-mile of dirt road on the system, in addition.

## Toll Road in Brazil

The government of the State of Sao Paulo, Brazil, has granted to a local company a 25-year concession to construct and operate an automobile toll road connecting Sao Paulo and Santos, at an estimated cost of $5,000,000. The terms of the concession provide that the road must follow a different route, except in short stretches, than that of the present highway known as the Caminho de Mar, that construction must begin within one year and be completed within three years from the date construction begins. The commissionaires are authorized to appropriate land houses, not only for the road itself but for guard and rest houses, parking spaces, and deposits of road building materials.

The full width of the road will be 30 ft. 4½ in. Of this width 21 ft. 4 in. will be paved with cement concrete. Grades are not to exceed 6 per cent, curves will have a minimum radius of 164 ft., and the shortest tongett between curves will be 131 ft. 3 in. Highways crossing this road will do so at a level above or below, thus eliminating all grade crossings, as the road will not cross a railway at any point. Certain short stretches, where the road will become one with the "Caminho de Mar," must be paved by the concessionaires with cement concrete to a minimum width of 19 ft. 8 in.

The concessionaires will have the right to collect tolls, the rates of which must be approved by the government, on all vehicles using the road except those belonging to the state. The toll charges will vary according to the type of vehicle, class of passengers, weight of car, its width, cargo capacity, and motor power.

At the end of the 25 years for which the concession is granted, the road will revert to the state without cost. At any time during the life of the concession the state may recover the road, paying the concessionaires its cost plus 15 per cent.

**New Belt Road Around Gloucester, England.**—Gloucester city council has decided to construct a new belt road five miles in length around the city which will carry through traffic and relieve the present serious congestion in the narrow streets in the center of the city. The new belt road will take traffic from the southwest of England, from a point at Tuffley, running via cemetery road across Painswick road to Coney Hill and Watton and continuing on to intercept the Gloucester-Cheltenham Road and the main Gloucester-Birmingham road. From there the road will run nearer to the city and end in the main Gloucester-South Wales road taking up traffic on the Gloucester side of the West-Gate Severn Bridge. The cost of the road is estimated to be $1,000,000.

# Water-Cement Ratio Method of Design for Highway Pavement

## Practical Application on Eleven Road Jobs in New Hampshire

By WALLACE F. PURRINGTON
Materials Engineer, New Hampshire State Highway Department

UNTIL three years ago the New Hampshire Highway Department determined the quality of its concrete based on an arbitrary mix. Its engineers considered this as unscientific and not producing the results that should be obtained. By this method advantage could not be taken of the difference in quality and grading of various aggregates. Because of this the department was purchasing concrete at higher prices than was warranted.

The first natural question that would arise when building a structure or pavement would be, how strong must this be designed to withstand the stresses that will have to be applied to it?

Assuming that this point is determined, the next logical thought that would interest the purchaser would be the question of cost. It is assumed that state highway departments, like every one else, have a limited amount of money to do business with, and, like the individual, are anxious to make a dollar go as far as possible.

Bridge structures are put up economically by using well-founded principals of design. These principles are not founded upon chance, but are the results of mathematical relations that have been slowly worked out. It has been the practice to divide concrete structures into three general classifications, such as mass, reinforced and highways. The usual practice for mass work has been to specify a 1:3:6 or a 1:2½:5 mix; for reinforced concrete, a 1:2:4 mix; and for pavement, a mix as rich as 1:2:3. To strictly comply with the specifications neither the contractor nor the inspector had any latitude to vary the mix that maximum results might be obtained from a definite set of conditions. There is not an engineer within my hearing who has not at some time wished that the mix he was using could be changed so that more workable concrete might be obtained.

Engineers are now becoming interested in the design of concrete mixes as well as in the design of the structure itself.

The purpose of this paper is to outline the practical application of the method of concrete design as applied to several highway pavement jobs in New Hampshire, pointing out the various steps to carry this out and giving the results obtained.

**The Water-Cement Ratio Law.**—This problem like many others is based on a premise. Our premise will be that the one most important condition pertaining to the production of concrete is the relation of water to cement. There are other factors entering into the manufacture of concrete which have a secondary bearing on our premise. These will be taken up in their proper order. The popular designation of our premise is the water-cement ratio law. This has been stated by the Portland Cement Association as follows:

For given materials and conditions of manipulation, the strength of concrete is determined solely by the ratio of the volume of mixing water to the volume of cement as long as the mixture is plastic and workable.

The information to be covered in this paper will be based on observations made upon eleven highway jobs which totaled 25.4 miles. The subject matter will include the following topics:

1. Preliminary inspection of materials.
2. Testing of materials.
3. Design of mix by the calculation method.
4. Selling the idea to the contractor.
5. Starting and controlling the job.
6. Inspection.
7. Results obtained.
8. Opinions of interested parties.

**Preliminary Inspection of Materials.**—The preliminary inspection of materials is very important, and the subsequent results are determined by the amount of work done at this time. Samples of the coarse and fine aggregates from the sources that are logical for the job are taken by some person from the laboratory. These should be carefully taken and should be representative of the quality and grading that could be supplied to the job. While it will be shown later that nearly any clean aggregates may be used in concrete, in our preliminary work we should use as great care as possible to choose the most economical material available. In general, the most economical aggregates are those which, when designed for a definite strength, use the least cement and the smallest quantity of coarse aggregate to the cubic yard. At this point it would be well to explain that the term "strength" will be used quite often. The other desirable qualities of concrete are not lost sight of, however. It is just as important to have dense concrete as to have the material highly resistant to abrasion. Fortunately, the other desirable qualities are functions of strength when economy is considered. Using the proper amounts of aggregates in both cases, we would not expect concrete designed for 3,000 lb. per square inch to have the same degree of density or the same abrasion loss, as that concrete designed for 1,500 lb. per square inch.

When local materials are under consideration for use, the accurate determination of the proportions that are to be used before the crusher and screening plant are in operation is a little difficult. Experience has shown that it is not impossible to determine these proportions approximately when the sizes of the revolving screens are known.

Recently, contractors have set up small washing plants in local gravel banks which are making clean and well graded sand and gravel at such low costs that a substantial saving to the state has been made.

**Testing of Materials.**—The whole scheme that we are discussing presupposes that the materials are clean, structurally sound and of standard quality. To this end, we test the cement, fine and coarse aggregate and in some cases the water. At present we are relying upon the modified Deval abrasion test to give us an idea of the acceptability of the stone or gravel.

Some one at some time conceived the idea that the measurement of the quality of sand for concrete could be carried out by the comparison of its strength tested in a certain way with a standard sand tested under the same conditions. We believe that this manner of testing is absolutely wrong and without foundation in theory or fact. Just so long as the sand under test is coarser than the standard sand we should expect to get as high or higher results. This test penalizes a fine sand. Every engineer knows that there would be no objections to the use of a fine sand if it were used under the proper conditions. Probably there is no one subject that makes the engineer or user more skeptical of laboratory results than reports that he has occasionally received relating to the quality of sands.

When you submit samples of sand to the laboratory for test you are anxious to know whether they are clean, structurally sound, and you should be also interested in their economy. You are

not particularly interested in whether this sand meets the requirements of some arbitrarily standard sand. What you want to know is, will this sand make good concrete? In other words, will this sand, either under test or on the job, be strong enough to use. It is quite as possible to design the strength of a sand mortar as it is to design the strength of concrete. For nearly three years we have been evaluating the quality of our sands by a method of test based on an application of the water-cement ratio method. In principle, the method of test is as follows:

Three hundred fifty-nine cubic centimeters of water are added to 600 grams of cement to form a paste. These quantities are in the same ratio as $6\frac{3}{4}$ gal. of water to the bag of cement. To this paste is added the sand under test until the mortar will show a flow of 200±5, using the flow table constructed from designs as furnished by the Bureau of Public Roads.

In order to carry out consistent tests with this method it is quite important that one brand of cement be used which should come from one mill. Two-inch cube molds are then filled and after storage in a damp atmosphere for 24 hours are stored in water for 6 days and 27 days longer. At the end of this time these are broken. In order to be classed as a normal sand the cubes should not break at less than 1,800 lb. per square inch in 7 days, nor less than 3,000 lb. per square inch in 28 days. Sands showing a strength less than these figures would be classed as weak.

On the basis of the sand being normal, we would advise the engineer that this sand would be satisfactory for use in concrete, allowing the use of $5\frac{1}{2}$ gal. of water to the bag of cement. If the sand showed low strength we would advise that not over 5 gal. be used. By cutting down the allowance of water we would thereby cut down the yield.

TEST RESULTS

WATER CEMENT—RATIO 0.9

Type of Specimen
2 inch cubes

| Cement Grams | Sand Grams | Flow | Water c. c. | 7 DAY 1 | 7 DAY 2 | 7 DAY 3 | 7 DAY Ave. | 28 DAY 1 | 28 DAY 2 | 28 DAY 3 | 28 DAY Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |

The sample of sand for use as Fine Aggregate as described above upon examination showed results as follows:

When mixed with cement and water on the basis of $6\frac{3}{4}$ gallons to the bag of cement this sample gave a strength of.................lbs. to the square inch at 7 days and.................lbs. to the square inch at 28 days.

From these results, in order to get the designed strength, the Laboratory would advise that for

Class A Concrete.................gallons to the bag of cement must be used

Class B " ................. " " " " " " " " "

Class C " ................. " " " " " " " " "

Other physical characteristics: Weight per cubic foot (dry and rodded).................

Color No.................Classed as.................Absorption.................%

Fineness Modulus.................Classed as.................

Specific Gravity.................Voids.................%

When made up as a mortar to the required consistency the mix would be 1:..........which is.................the average yield.

.................

Materials Engineer.

**Laboratory Card**

Under ordinary conditions this fact would discourage its use.

We take the position that under the proper conditions any clean—and we would emphasize the word clean—and structurally sound sand may be used in the manufacture of concrete.

Your reply to this would be, in effect, that a weak or an extremely fine sand would not be economical. When you reply in this manner you are "beside the point." The primary function of a testing laboratory is to determine the quality of materials, not to study economics. When the quality of the material under observation has been determined, the laboratory might properly advise interested persons as to its economical use. We will show later that this advice has been to the mutual advantage of both the contractors and the state.

**Design of the Mix by the Calculation Method.**—The next step in our problem, after the choice of materials has been made, is to take these materials and combine them with cement in the most economical way. There are two schemes by which this can be done. These are termed the trial and calculation methods. There is no great advantage to the state in letting the contractor use the trial method on a job that calls for a large quantity of concrete. Carrying out this method a contractor is told the amount of water that can be used to a bag of cement, and then he manipulates his aggregates by trial in such a way that he gets the most workable mix. This does not necessarily give the most economical combinations of material. If the water-cement ratio scheme was dependent upon this, in all probability neither the contractor nor the state would be satisfied with the results obtained.

We determine all of our mix proportions by the calculation method. This method and all the steps involved are clearly explained in the 1927 edition, "Design and Control of Concrete Mixes," published by the Portland Cement Association. The mathematics involved are very simple. A set of scales, screens and containers for determining the weight per cubic foot is all the equipment necessary.

Let us now take up the steps that are necessary to design a mix of concrete for use in a highway pavement job in New Hampshire. We state in our specifications that the contractor shall not use more than $5\frac{1}{2}$ gal. of water (including the water in the aggregate) to each bag of cement (assuming the cement to weigh 94 lb.). This is a fixed value and cannot be changed. On a pavement job at the best the proportioning will never be carried on as accurately as in the laboratory, so we refer to the well known Abram's Curve, and find that $5\frac{1}{2}$ gal. of water hits the B Curve at about 2,700 lb. This, then, becomes our basis of design. We do not want too sloppy a mix, neither do we want it to be too dry; therefore we decide that a mix which will give a slump of from 3 to 4 in. will produce the right workability. We have now determined the consistency that we are aiming for.

When we mix cement and water together we form a mineral glue. We now want to use this glue to coat the sand and stone particles and cement them together. If we used all sand particles we would find that our glue would not go very far. If we used all stone particles we would find that our glue would go far enough, but that we would have too high a percentage of voids, and we would lose the desirable quality of density. By the use of more sand and less stone we finally come to a place where we get the mix which will give the densest, most economical and strongest concrete for the given conditions. It is not the purpose in this paper to give all the details of the method of calculation, only repeating the statement that this is easily available to interested parties.

We report to the contractor the mix proportions on the dry and rodded as well as on the field basis. On the dry and rodded basis is determined the barrels of cement and the quantities of aggregates necessary for a cubic yard of concrete. Preliminary to starting the job the laboratory makes up a mix, using the same aggregates and cement that are to be used on the project. This gives us a chance to make any minor corrections and suggestions that may be advantageous. When the actual operation of mixing commences, the contractor is interested in the quantity of materials he will have to use under the conditions prevailing at the time. As all our contractors proportion by volume, it is necessary to determine the percentage of moisture and the weight of the material per cubic foot in the damp and loose condition. The bulking factor is taken account of in our design.

At this point we have worked up the preliminary data, and are now ready to furnish the information to the contractor.

**Selling the Idea to the Contractor.**—Our department takes the position that a close cooperation between its engineers and the contractor will eventually be reflected in lower prices for projects. To this end, for this type of work, it places at the disposal of any contractor the facilities of its laboratory, both preceding and during the progress of the job. This fact is definitely a part of the specifications and it means exactly what it says.

The contractor's first reaction to this offer may be skepticism. There may be two definite reasons, based possibly on past experiences, for his unfavorable attitude. He might be suspicious that some one was trying to "put something over on him," or that the laboratory was too theoretical.

We are perfectly safe in saying that our State Highway Commissioner would never have approved or adopted the water-cement ratio method unless he felt that quality concrete could be produced at lower cost. Neither would he have tolerated the carrying on of experiments which would have resulted in increased costs or hindrance to the contractor.

Assuming, then, that the interests of the contractor and the state are identical, in that they both want a good job done, and that they both wish this job carried on with the least expenditure of money, they are both in a position to establish cordial business relations. We will cite an incident as to how this actually worked out. A certain contractor came to the laboratory and told us that he was about to bid on a 5-mile concrete pavement job and wanted information as to the proper use of aggregates. We went with him on the day preceding the opening of bids and looked over the logical source of supply of aggregates. From information which we had in the laboratory he was given suggestions as to the mix he might use. We told this contractor he might use as little as 1.40 bbl. of cement to the cubic yard of concrete if these materials were used. He told us that this would cut his bid considerably. He had planned to figure 1.70 bbl., the same as he always did. We, of course, did not assure him that 1.40 bbl. would be a guaranteed maximum, but that if he would take the proportions suggested and would furnish material to the job the same as the observed material, we felt positive that he would check our prediction by actual practice. Data on the five miles show a difference of 0.02 bbl. per cubic yard higher than the designed figure. We feel almost certain that all usual cases will show such comparisons. His bid was 15 ct. per square yard below the next higher bidder.

On the next project two contractors came to us for information. The low bid on every job but one during the past year has been awarded to the contractor who has consulted the laboratory before putting in his final figures. There has been no especial urging necessary on our part to have contractors consult with us. We stand ready at all times to furnish such technical information as is necessary. It requires only one experience with the economical features of these specifications to sell any live contractor.

Referring again to the incident mentioned above, we would like to call your attention to the fact that this contractor was no theorist, but a far-sighted business man out to make the job pay. There were two things that he might have done other than accept our figures, viz., worked out his mix by the trial method, or carried out the calculation of the mix by members of his own organization. We do not insist that our figures be used. There are two things, and two only, that we do insist upon, and they are that he uses no more water than he is allowed, and that the resulting concrete be plastic and workable. One of our big problems, at first, was to convince the contractor that the water-cement ratio method was workable. This called for salesmanship. Later in this paper we will give the contractor's answer as to whether or not we were good salesmen.

**Starting and Controlling the Job.**—Just before the contractor is ready to start casting, the laboratory, with the field inspection force, check the measuring devices used for the measurement of water and aggregates. From our preliminary work we have information as to the mix that may be used. The inspection force sets the batch boxes to fit the figures furnished by the laboratory. The batches are then taken to the mixer, where water is added to give a slump of from 3 to 4 in. Repeated checks on the above method have shown that with the designed mix not more than the allowable quantity of water is necessary to get the degree of workability and quality of concrete desired.

The following statement can be proved by two inspectors, the superintendent, the foreman of the mixing gang and the mixer man.

Not once during the laying of three miles of a concrete road job was the water changed, and only once was it necessary to change the quantity of aggregates, and this was due to the fact that the grading of the aggregates was slightly different. We wish to emphasize the above fact, for we have heard it stated many times that it was impossible to carry on a job without considerable adjustment. We will also state that this job was laid on very level land, which was a favorable condition. On another job laid by the same contractor, he was able to build about two miles of road without changing the mix from that furnished originally by the laboratory. This was a hilly job. Here we kept the mix and the slump constant. Owing to the mechanical construction of the water delivery system we were obliged to change the reading on the water gauge when going up and down a grade. While there was an apparent difference as far as this gauge was concerned, the same amount of water was actually delivered in each case. No change of the amount of aggregates was made on still another job, built by a wholly different contractor, but we changed the reading on the gauge once, due to a very stiff grade. We also found that the ordinary rain storm did not affect the amount of water in a stockpile to any great extent. Should a heavy rainfall occur, we would have no objections to allowing the mixer man to cut down his water for a short time until moisture conditions came back to normal. Our inspectors would see that the mix was not changed and that the same degree of workability was maintained. All three of these jobs were built of imported, washed aggregates. It is our experience that concrete roads should be built of nothing but washed sand and gravel or clean crushed rock. Such a recommendation has been made to our commissioner for all future work. The extra cost for washed material is small, but results in quality and economy of the finished product are great. When an unwashed material is used it is impossible to maintain uniformity of product as well as to keep it free from dirt.

**Inspection.**—Without the enthusiasm and interest of our inspection force the carrying out of the method would have been difficult. Each member of this force was definitely told what was to be accomplished and the manner in which it was to be done. We tried to convey the idea to him that we had simply set up the laboratory for the time being in the field, and that the job was a laboratory experiment in which he was a vital part. It was not long before the inspector as well as the contractor's representatives caught the spirit of the idea, and throughout the various projects even the ordinary laborer wielding a shovel took pride in helping produce the results that were obtained.

During the progress of the work we cast beams from the mix after it had been deposited on the ground. From five to seven days later part of each beam was tested. When the beams showed a modulus of rupture of 350 lb. or over to the square inch, the contractor was notified that he might have the road for his own use. This not only expedited the work but made a definite saving of money to the contractor in addition to giving the road to the public at the earliest possible moment.

We cast beams also which were broken at the end of 28 days. After these beams were removed from the molds, they received the same treatment that was given the pavement.

Considerably higher results would have been showed if these beams could have been immediately stored in a damp closet under standard storage conditions. We were more interested in what strength developed under actual conditions than we were in the strength that might develop in an artificial manner. We are perfectly safe in the assumption that beams stored under the above conditions will give us the minimum strength that the concrete would show. Slump tests were carried out in order to check the workable conditions of the mix. On these jobs a uniform system of records was kept. On each of these projects a maximum and minimum thermometer was used in order that temperatures might be recorded.

**Results Obtained.**—"A man is measured by his works." This might be paraphrased to cover the problem that we are discussing as follows: The theory sounds fine, but what about the results? In other words, can the same kind of concrete be made under field conditions in wholesale quantities, that a laboratory worker can put together in a small way? All highway pavement concrete in New Hampshire is designed to give a strength after 28 days of 2,700 lb. to the square inch. We do not expect to get as a result concrete much stronger than this. If we wanted stronger concrete it would be a simple matter to bring it about through our design.

At the time of bidding, the cement factor that might be applicable to the job is furnished the contractor. Each day this is checked, based on the amount of concrete placed and on the number of bags of cement used. At the end of the job the average factor is calculated. The following tabulation of results has been obtained from eleven jobs where accurate records have been kept. The cement factor on another job is given.

**Tabulation of Results**

| | | Compressive Strength* | | | Cement Factor bbl. cement per cu. yd. | |
|---|---|---|---|---|---|---|
| Project | Mileage | Designed lb. per sq. in. | Obtained lb. per sq. in. | Modulus† Rupture | Designed | Obtained |
| Dublin, 1927 | 1.77 | 2,700 | 3,135 | 570 | 1.45 | 1.51 |
| Dover | 5.03 | 2,700 | 2,810 | 511 | 1.40 | 1.42 |
| Claremont, 1927 | 2.01 | 2,700 | 3,000 | 551 | 1.45 | 1.49 |
| Concord, 1928 | 2.68 | 2,700 | 2,975 | 541 | 1.40 | 1.32 |
| Lebanon, 1928 | 2.29 | 2,700 | 2,750 | 500 | 1.40 | 1.40 |
| Manchester | 2.48 | 2,700 | 4,050 | 735 | 1.46 | 1.58 |
| Salem, 1928 | 1.58 | 2,700 | 3,670 | 666 | 1.45 | 1.55 |
| Dublin and Peterboro, 1928 | 3.15 | 2,700 | 2,640 | 480 | 1.36 | 1.44 |
| Claremont, 1928 | 1.90 | 2,700 | 2,673 | 486 | 1.50 | 1.46 |
| Tamworth, 1928 | 1.70 | 2,700 | 3,075 | 559 | 1.56 | 1.54 |
| Lebanon, 1927 | 0.85 | | | | 1.42 | 1.47 |

*Conversion figures.
†Twenty-eight days.

From these figures it would appear that the greatest variation in the quantity of cement used was on the Manchester project, and this was only 0.12 bbl. The fact should be appreciated that our design was based on a theoretically perfect subgrade which would use neither more nor less than 35.2 cu. yd. of concrete to each 100 ft. of 18 ft. of road. Also these figures do not allow for wastage. On the Lebanon job there was a difference in the amount of cement used on each half of the job of only 20 bags.

So much for the contractor. It is now time to look at the results which have accrued to the state. The benefits to the state can only come in maintaining the quality desired, and at the same time in saving money. Reference to the above tabulations will show that we were furnished with a satisfactory grade of concrete. We did not receive 4.000 lb. concrete, neither did we ask or pay for it. It is quite true that cement prices were somewhat lower in 1927 and 1928 than in 1926 but, at the most, this difference would not lower the price of a square yard of concrete more than three cents.

The following is the comparative data for costs of concrete for 1926, 1927 and 1928 as built under the supervision of the New Hampshire State Highway Department:

**1926**

| | Sq. Yd. | Unit Price | Total |
|---|---|---|---|
| Landaff | 3,000 | $2.75 | $ 8,150 |
| Manchester | 10,400 | 2.65 | 27,560 |
| Exeter | 14,334 | 2.74 | 39,285 |
| Total | 27,734 | | $74,995 |

Average price per square yard, $2.74.

**1927**

| | Sq. Yd. | Unit Price | Total |
|---|---|---|---|
| Dover | 53,096 | $2.15 | $114,156 |
| Salem | 13,600 | 2.25 | 30,600 |
| Lebanon | 8,998 | 2.44 | 21,955 |
| Claremont | 21,738 | 2.45 | 53,258 |
| Lisbon | 4,012 | 2.36 | 9,468 |
| Dublin | 18,644 | 2.55 | 47,542 |
| Tamworth | 18,556 | 2.23 | 41,379 |
| Bedford | 13,291 | 2.25 | 29,904 |
| Total | 151,935 | | $348,264 |

Average price per square yard, $2.291.

**Cost Data on Concrete Pavements, 1928**

| | Unit Price | Sq. Yd. | Total |
|---|---|---|---|
| Tamworth 237-B | $2.32 | 18,226 | $ 42,284 |
| Lisbon 232-D | 2.23 | 14,902 | 33,231 |
| Lebanon 212-F, 201-F | 2.15 | 24,362 | 52,378 |
| Milton 224-B | 2.00 | 21,120 | 42,240 |
| Keene T. L. C. | 2.20 | 17,297 | 38,053 |
| Lancaster 231-B | 2.40 | 15,800 | 37,920 |
| Wolfeboro 213-C. & T. L. M. | 2.35 | 26,033 | 61,177 |
| Peterboro 217-E | 2.40 | 12,004 | 28,809 |
| Dublin 235-B | 2.70 | 17,780 | 48,006 |
| Manchester Bedford | 2.15 | 24,595 | 52,879 |
| Concord | 1.80 | 47,454 | 85,417 |
| Auburn | 2.18 | 17,134 | 37,352 |
| Claremont | 2.25 | 22,600 | 50,850 |
| Franklin | 1.80 | 33,940 | 61,092 |
| Salem | 1.97 | 16,776 | 33,048 |
| Total | | 330,023 | $704,739 |

Average cost per square yard, $2.136.
Total mileage, 30.7.

If 1927 contracts were let at 1926 prices, the additional cost to the state would have been $68,150. On the same basis it would have cost $202,000 extra to carry out the 1928 program.

**Opinions of Interested Parties.**—Earlier in this paper we mentioned the fact that part of our problem called for salesmanship. There would not be a great deal of profit accruing to the state in the adoption of the method under discussion unless the contractor used information which was available to him preceding the opening of bids. We want him to use as low a cement factor as is consistent under the conditions, and have the lower cost of cement reflected in his bid. To this end our department encourages its laboratory to furnish the contractor with any information relative to economical mixes which he may request.

Recently we sent out a questionnaire to one of our leading contractors. This questionnaire, in its exact words and the answers, is given below. This contractor stands very high in the roadbuilding industry. These answers are not written to flatter, but represent facts.

**Contractor's Questionnaire**

Question.—What was your opinion of the water-cement method of control before trial?

Answer.—Rather skeptical.

Question.—What is your present opinion, and why?

Answer.—We are in favor of this method because we are able to get a better working mix, and it also saves us money on the amount of cement used.

Question.—Did you know that before bidding the job the laboratory facilities of the State Highway Department were at your disposal to furnish the theoretical quantities of material that might be advantageously used by you in the manufacture of concrete on the job?

Answer.—Yes.

Question.—Did you take advantage of these facilities?

Answer.—Yes.

Question.—The average cement factors for your two jobs as computed by us were as follows:

| Job. | Designed Factor (Bbl.) | Factor Used (Aver. Bbl.) |
|---|---|---|
| Dover-Somersworth | 1.40 | 1.42 |
| Dublin | 1.45 | 1.51 |

Question.—From your experience, is this difference any greater than with an arbitrary mix?

Answer.—No special difference from arbitrary mix, but any difference would be from the grading of the aggregate which seems to control the amount of cement used.

Question.—There are two men in your organization who probably come in contact with concrete operations more closely than do you yourself, viz., the superintendent and the foreman at the mixer. What is the opinion of the superintendent, of this method?

Answer.—The superintendent agrees with the above statements.

Question.—What is the foreman's opinion?

Answer.—None.

Question.—The New Hampshire specifications allow the use of coarse aggregate up to 3 in., but contractors are not using aggregate larger than 2½ in. It might be possible to design a mix reducing the quantity of cement without impairing the quality of concrete by using a little larger aggregate. Is this idea feasible?

Answer.—Yes, but the amount of stone larger than 2½ in. would have to be carefully regulated so as not to affect the finishing. There would surely be the tendency to put in more of the large stone, especially if coming from a commercial plant.

Question.—From the contractor's viewpoint please give any criticism of last year's work as it applies to this problem. We would gladly receive any suggestions that you might offer for the future.

Answer.—We feel that it is impossible to have a set formula for concrete road work, and do feel by your method of having a certain amount of cement and water, but varying the proportions of the aggregate, you get a strong concrete and save us money, and this also is reflected in the prices that are bid for the work which saves the state money.

**Conclusion.**—The study that we have given to the manufacture of concrete during the past two years has been very interesting. It has convinced us that the water-cement ratio method is sound in principle and practicable to

apply on the job. It has created a very fine spirit of cooperation between the contractor and the representatives of the state. It has given us quality concrete at a reduced cost. This lowered cost has made it possible to extend the building of this very fine type of pavement in our state.

**Acknowledgment.**—The above paper was presented Feb. 13 at the annual convention of the North Atlantic State Highway Officials' Association.

## Annual Meeting of American Road Builders Association

The annual meeting of the American Road Builders' Association will be held in Washington, May 2 and 3, 1929. On Thursday, May 2, there will be a reception by the president and the directors at the offices of the association, National Press Building, Washington, D. C., from 3:00 to 6:00 p. m.

The regular annual meeting of the City Officials' Division will be held Friday morning, May 3, at 11 o'clock, at the offices of the association. The reports of the board of directors and officers of the division will be presented at this meeting, and such other business as may be deemed necessary will also be transacted.

The regular annual meeting of the County Highway Officials' Division will also be held Friday morning, May 3, at 11 o'clock, at the offices of the association. At this meeting will be installed the officers and directors elected at the recent meeting in Cleveland. The reports of the board of directors and of the officers of the division whose terms expire at this meeting will be received and any other necessary business transacted.

The annual dinner of the association will be held at 7:00 p. m. at the Willard Hotel.

The regular annual meeting of the American Road Builders' Association will be held Friday evening, May 3, at the Willard Hotel, Washington, D. C., immediately following the annual dinner of the association.

The officers and directors elected at the recent convention in Cleveland will be installed at this meeting and the reports of the board of directors and of the officers whose terms expire at this meeting will be received and such other business transacted as may be deemed necessary.

**Motorized Pennsylvania.**—Automobile license totals for 1928 indicate that Pennsylvania now has one vehicle for each 7.18, the Pennsylvania Department of Highways announces. Thirty-six other states have a lower ratio of persons per car, but Pennsylvania stands third on the list of total cars licensed and only 383,000 below the highest total, which is for New York.

## Asphaltic Mixed Macadam in Ontario

By R. M. SMITH
Deputy Minister of Highways of Ontario, Canada

When hard surface is required we confine ourselves almost entirely to concrete and asphaltic mixed macadam. Concrete receives first place in Ontario's highway paving program. While sheet asphalts and asphaltic concrete surfaces are quite extensively laid, the square yardage is small compared to our development of what we have classified as "Asphaltic Mixed Macadam." A paper dealing with this type of construction was read before the Washington Convention of the Asphalt Association in 1926. At that time only a limited mileage had been built, more or less of an experiment. I am pleased to say we are well beyond the experimental stage and that the pavement has proven a success. Our original intention in undertaking the construction of this type of pavement was to improve on the construction of penetration and at the same time provide a surface that could be built without detour or inconvenience, moderately priced. The pavement has met these requirements. Further, its non-skid surface has recommended it to the motorist, the riding qualities being equal to those of a high-class gravel road.

As explained at the 1926 conference, the construction of this pavement is simplicity itself— a matter of crushing the stone as it comes from the wayside quarry to a size that all material will pass a 2-in. ring.

It might be explained here that Ontario limestone rated for hardness would possibly be considered soft, running an average of 5. It has a peculiar characteristic, however, in that the stone hardens under exposure. Further than that, the stone fractures fairly close to sizes required in our aggregate running approximately 20 per cent passing 2 in. and retained on 1 in., 40 per cent passing 1 in. and retained on 1/4 and 40 per cent passing 1/4 screen. Paving asphalt penetration 71-80 is used in the mix.

The crushed stone as it comes from the crusher is charged directly into the asphalt plant, adding approximately 4.75 per cent asphalt by weight and the product is ready to be placed on the road. Burch or Galion spreaders materially assist in the spreading, after which the pavement is consolidated. In Ontario the completed surface is about 6 in. in thickness, the depth, however, depending largely upon the condition of the old subgrade. As the contract is let on a tonnage basis, the engineer in charge is expected to use his own judgment. Approximately 400,000 tons of mixed material were placed in the road surface last year.

After the pavement has been thoroughly rolled, but just before final consolidation, 3/8-in. stone chips are applied. Traffic is then permitted to pass over this road for a short period, following which the surface is treated with 60 per cent asphaltic road oil, approximately 1/8 Imperial gallon per square yard, followed by a second application of chips, the quantity of chips dependent upon the closeness of the surface.

The Department has at no time contended that this type of pavement meets all the demands that might be made by the asphalt technologist, nor do we claim that it is the highest type of asphaltic pavement that can be laid. We do, however, feel that it is serving a real purpose in that it is supplying in the first place a pavement that can be laid under traffic. Second, it can be laid under almost any condition. An unsettled grade is not a serious detriment as an additional levelling up surface can be added at any time to bring the road back to grade. The pavement when completed will provide a surface more or less permanent in type suitable to carry traffic for many years. When the time comes that a higher type is required, the asphaltic base 100 per cent salvage value will be there to receive it.

When the Department first undertook the laying of this pavement, it was contended by some engineers that the voidage content would be too high; that the pavement was much too open. Numerous samples obtained from the pavement, however, indicate a dense close mix, the crushed stone of the various sizes forming a perfect key. The weight of the surface will average 105 lb. to inch of depth per square yard.

Another criticism that we received in the early stages of our construction was to the effect that surface-treating which apparently was necessary and which would likely require repetition every second year was objectionable and a condition not to be desired. As a matter of fact one short section laid in 1921 has received no attention whatever since it was built and has the appearance of not requiring treatment of any kind for years to come. Further than this, no ravelling has taken place. This applies on all our pavement so far constructed.

We feel this pavement has justified our faith that its development is to be recommended. At the present time we have completed 170 miles, our future program providing for extensive construction. The cost, as stated before, is moderate, the average price paid this year where commercial stone was used being $5.90 per ton and $5.45 where local stone was used.

**Acknowledgment.**—The above is an abstract of a paper presented at the 1929 Conference on Highway Engineering at the University of Michigan.

# Hot Mix Type of Highway Surfacing

## The Earlier and Present Methods in Massachusetts

By HOWARD C. HOLDEN
District Highway Engineer, Massachusetts Department of Public Works

IT may be of interest to review briefly some of the earlier methods used in the placing and mixing of this type of surface.

**Early Sand-Asphalt.**—In the early days the sand-asphalt surface, known as the layer type, was first placed in the town of Eastham in 1905. Compared with the modern method of spraying asphalt the operation was very crude. An upright tank, similar to an enlarged "hogshead," was used as a container and hauled by four horses. The subsoil of sand was roughly shaped and harrowed with a disk or wheelbarrow, so one can readily imagine how it was rutted by the wagon, and the holes caused by hoof imprints. The flow of asphaltic oil was controlled by a gate valve. This controlled the amount delivered to a distributor pipe having holes bored through it, the holes being about one-half inch in diameter and about 3 in. apart. The effect was very streaked application. Later a distributor was used by which the asphaltic oil was distributed through nipples on to a splashboard and to the road surface. This was an improvement, but still very crude. One wonders now, when he visualizes these methods, that as good results were obtained. The bitumen consisted of 85 per cent asphaltic oil. Applications consisted generally of two, of about ¾ gal per sq. yd. the first application being covered with sand and back-covered daily for about a week. The surface was then broomed as clean as possible and the second application applied. This type with constant maintenance produced an uneven road surface, and is now occasionally built by towns in Barnstable County on unimportant roads. However, at the present time the subgrade is hardened, properly shaped and the bituminous material applied with uniform distributors under proper pressure.

**The Oldest Sand-Mix Type in Service.**—The oldest highway of the sand mix type now in use on our state highway system is on National Route 6 in the town of Sandwich. The mixing operation for this project was carried on by placing a fixed volume of sand in a box similar to the old-time mortar box, and adding the proper amount of 90 to 100 penetration asphalt and raking it back and forth until the same particles were coated. This product was wheeled in barrows or carted to the highway and spread in one course to a thickness that would roll to 3 in., first rolling with a hand roller, then a horse roller, and generally a final rolling at some later date with a 10-ton 3-wheel macadam roller. This highway surface is still in use and extends from the Bourne-Sandwich town line to the village of Sandwich. This surface was placed in 1913, and since it has received two surface treatments of ¼ gal. each of 85 per cent asphaltic oil. Each time it was covered with clean, sharp sand. Soon followed the use of cylindrical dryer and cube mixers which established a portable plant, also the semi-portable plant, and the permanent plants of a larger type.

**Selection of Sands.**—At the present time the Sandwich project is the only hand-mixed surface of this type which has not been resurfaced, except one short section in the town of Mashpee, near the Barnstable line. The Sandwich highway today is narrow, supercrowned, and reconstruction must soon occur. From 1912 to 1922 very little attention was given to selecting sands which were properly graded, in general, a fairly coarse, clean sand being used in the mix, the one exception to this being in 1917, when 5 to 10 per cent by volume of Portland Cement was added to the mineral aggregate. Very naturally this somewhat increased the asphalt content. At this time it was decided that while excellent results were obtained by using the Portland Cement as a filler, it was felt that the results were satisfactory using local sand, and the cement filler increased the cost of the surface beyond the value received. Until 1920, on all of the so-called sand and oil-mix surfaces, on completion of the surfacing the surface was sealed with two applications of ¼ gal. each of 85 per cent asphaltic oil, and the surface covered after each application with sand.

Prior to 1921 this type of surface was always placed in one course. Very often during the summer months the section placed in the afternoon was not rolled until the following day. This did not give proper compression, and in a short time traffic created inequalities of surface. The lack of using side forms, together with the excessive crown and narrow width, caused the edges to break down under traffic. Today, with the lesser crowns and the use of wooden side forms on the top course, and with the base course slightly widened, the breaking down of edges has been corrected.

**The Rod Penetration Test.**—In 1922 quite extensive experiments were conducted in Wellfleet. At that time it became evident that it was necessary to increase the stability of this type of surface—to ascertain just what could be done to prevent displacement of the surface when loaded vehicles stood upon the surface during the season of high temperature; that certain factors were important, namely, load, time and temperature, and the depth penetrated by load; and just what could be added to the mineral aggregate to increase the stability of the surface. To ascertain this we used the rod penetration method, which is, briefly, a rod of certain cross-section area held in position by a small tripod and fixed loads added for a fixed time. The experiments with load and time applied were carried out during approximately the same temperature, thus obtaining comparative results from the different mineral aggregates used, which consisted of sand, stone screenings and hydrated lime in various amounts. At this time we had no method of arriving at density determination other than visual inspection. However, very careful observation of time of rolling and temperature of mix on the road surface was kept. At this time it was found very desirable to place the surface in two courses, and we also used side and center forms of wood, and the practice of using forms has been continued until the present time. Original rollings were done with a 6-ton tandem roller, and final rollings with a 10-ton 3-wheel macadam roller. It was found the same results were obtained with the tandem as with the 3-wheel roller. This conclusion was arrived at by the use of the rod penetration method, and comparing load, time, temperature and penetration.

The use of this simple device also provided an approximate idea of impact or stability value where these experiments were tried. First, the load was applied to the rod and as near uniform blows as possible were used, and a record of the number of blows and the character of the results were studied. From these various experiments was created our present Type A Bituminous Concrete Specification. I should add that many screen tests of sand were made, curves plotted on cross-section paper, and we thus determined the most desirable grading of sand particles. Mr. G. H. Delano was district engineer in District 7 at this time, and to him should be credited the persistent effort to improve this type of surface, which has become known to the Department of Public Works as Bituminous Concrete, Type A.

**The Type A Surfacing.**—The Type A surfacing is the type most commonly in use at the present time. In addition to the mileage of this type of surface on the present state highway system there exists many miles in southeastern Massachusetts on roads built entirely by the towns, also a large mileage exists on chapter 90 or co-operative projects, where state, county and town provided funds. These chapter 90 projects were built under the supervision of the Department, and are maintained by the towns. A very economical type has been constructed on chapter 90 work by crushing gravel and using the larger product of the crusher for a base course, filling the voids in the base with the finer aggregate, or penetrating the base course with refined tar or asphalt, and over which has been placed a top course of 2 in., using the finer aggregate from the crusher product. This type, with the base course of crushed gravel which has been varied from 2 to 4 in. in thickness, gives a more stable surface.

Much of the sand and asphalt work done in Barnstable, Dukes and Nantucket Counties has been resurfacing and widening, as well as just widening the old water-bound macadam and reducing the crown. It has not been the custom to scarify the old macadam surface; simply place the full thickness of the base course on the widened portion, and true up the old macadam surface to a uniform cross section, and then place the top course of 2 inches in thickness. This has provided a very economical method of resurfacing as well as one which has been very satisfactory.

The highways constructed and reconstructed with this type of surface are within an area which, during the summer months, carry a medium to heavy automobile travel, but are not subjected to heavy truck traffic. In Barnstable, Dukes and Nantucket Counties the law limits the load, including vehicle, to 10 tons. I do not recommend this type of surface for a highway over which passes a large number of heavy loaded vehicles. On Nov. 30, 1928, the total mileage in District 7 of this type of surface was 157.94 miles, and the surface maintenance cost without surface treatment was $45.68 per mile, while the surface cost for the 157.94 miles, including the surface treatment, was $102.34 per mile.

**Method of Making Surface Repairs.**—This type of surface is simple to repair, as plants are quite numerous in Barnstable and Plymouth Counties. The customary method of making surface repairs is to cut out the section that needs repair. By this I mean removing the top course, painting the edges of the section, cut out lightly, and spattering the base course with bitumen so as to give a cobweb effect. It is customary to buy this material from the various local plants all mixed, and fill in the areas cut out and roll it with a hand roller, and, if available, use a tandem roller. The bituminous concrete or sand asphalt surfacing material can be hauled for quite a long distance. If it has a tendency to cool it can be covered. Also when rolling with a hand roller the type that can be filled with hot water can be used in cold weather. After the surface patch is made it can be sealed, and the patches present very nearly the same appearance as the original surface.

During the past few years a special effort has been made to correct inequalities in the surface, not only on this type but on all types of surface. On this particular type of surface, to increase the density, equipment has been placed on the rollers so that they are wet with water, and this has prevented the picking up of the surface, and the rolling has been done sooner after the surface material has been placed. In the initial rolling care should be used that the roller travel parallel to the center line of the pavement, beginning at the edge and working toward the center, being sure that the roller shall overlap the preceding one about one-half the width of the roller. It is important that the roller, when changing direction, does not stand on the hot surface, and it is necessary that the rakers resmooth the surface at the point where direction is changed. This particular type of surface is pliable when hot, and inequalities in the surface, such as low spots, high spots or depressions, can be raked out and then hot additional material can be added to correct this condition, but immediate rolling should occur after additional material has been added. During the past year all projects have been equipped with straight edges 10 ft. in length, and a great deal of attention has been paid to correct the irregularities by the use of this straight edge, and all low or high spots ¼ in. and over have been marked with yellow crayon and rolled out. This operation has been continued until the surface is free from such irregularities.

**Density Studies.**—During 1928 the Federal government placed inspectors on various Federal aid projects, primarily to study methods and to see if suggestions could be made to reduce the cost to the contractors in the placing and manipulation of this type of surface. Quite intensive studies were made by them for density determinations. During this study two density determinations of ten complete sets of cylinders were made. A 2-in. steel pipe sharpened on one end was used to take samples, the first sample being taken as soon as the roller had passed over the surface, and they were able to force the core cutter through the top course by hand. After further rolling, it was necessary to drive the core cutter through the surface, or use a jack, and jack through the top course to obtain the sample. The core cutter was lightly oiled with linseed oil and the sample could be easily pushed out. Continuous samples were taken until the final rolling occurred. A careful record of temperature was made at the time of rolling, and the temperature of the air was taken when the final core was obtained. The results they obtained were interesting, and it was found that the density was practically the same, whether the surface was rolled with a 6 or 9-ton tandem roller.

**Use of Ground Limestone.**—In the fall of 1928 experiments were conducted using ground limestone in the place of stone screenings. The use of ground limestone presents a surer continuity of uniformity. To illustrate just what is meant, let us assume that the hopper is of sufficient size so that 1,000-lb. batches can be mixed, as the limestone almost always comes in 100-lb. bags. This means that a proper amount of limestone dust can always be added. A visual inspection of the section constructed using limestone indicates a slightly more stable surface, and I am of the opinion that in the long run the operation can be reduced slightly in cost by using limestone rather than stone screenings. My reason for this is that the limestone is not heated. It is added to the hopper direct from the bag, so that both elevators can be used in raising sand to the dryer.

It has been found that the output in general is slightly slowed up because one elevator does not carry sufficient sand to the dryer when the other elevator is used for raising stone screenings, so that I feel that a greater output can be obtained, even though it will be necessary for a few revolutions of the pug to mix the sand and limestone dust before adding the asphalt.

**Acknowledgment.** — The foregoing paper was presented Feb. 27 before the Highway Section of the Boston Society of Civil Engineers.

**$8,000,000 Bond Issue for New Hampshire.**—The New Hampshire Senate has passed the bill that provides for an $8,000,000 bond issue for the construction and reconstruction of permanent trunk line highways in New Hampshire. The measure has been sent to the Governor for his signature. Under the bill, expenditures of $1,500,000 will be made in 1929 and 1930 and $1,000,000 a year during the following five years. A companion bill that provides for a $750,000 appropriation to assist highway work in various communities has passed the Senate.

**Road Construction in Hungary.**—Construction of 124 miles of new roads will begin this spring. The names of successful bidders for the work have not been announced, but it is reported that the major portion of the work will be done by a company controlled by the Hungarian General Credit Bank, Budapest.

# Effect of Increased Speed of Vehicles on the Design of Highways

## A Summary of Present Highway Design Practice

By A. G. BRUCE

Senior Highway Engineer, Division of Design, U. S. Bureau of Public Roads

A STUDY of the speed limits now imposed by the various states shows a decided increase over those imposed 10 years ago. In 1918, three states had speed limits of 35 to 45 miles an hour, and eight states had no limitation. In 1928, 36 states permitted speeds up to 35 to 45 miles per hour and 3 had no limitation. The speed limitation predominating in 1918 was 25 miles per hour, and in 1928 it was 35 miles per hour.

A great many users of the highway travel at speeds much higher than the legal limit, especially in those states with the lower limitations. The models of motor cars produced in recent years are all capable of relatively high speeds, and the general trend toward increased braking capacity and greater riding comfort has given drivers a sense of greater security at high speeds. Taking into account the more liberal legal speeds, the difficulty in rigidly enforcing a speed imitation, and the greater possible speed due to improved roads and improved cars, it appears safe to estimate that the average speed on the open road today is fully 20 miles per hour greater than it was 10 years ago.

Studies made in connection with the Cleveland survey* show that passenger vehicles on the open road where traffic is far below full capacity generally travel at a speed varying from 30 to 40 miles per hour.

This increased volume and speed of motor-vehicle traffic requires smoother and wider road surfaces, easier curves, wider shoulders, shallower ditches, greater superelevation of curves, more extensive use of vertical curves, longer vertical curves at the top of hills, greater sight distance on both horizontal and vertical curves, the avoidance of compound curves, more adequate guard rails, more adequate protection at railroad grade crossings, and special treatment of intersections of heavy-traffic highways.

**Width of Surface.**—The safe passing of rapidly moving automobiles and buses requires a surfaced width of at least 20 ft. for a 2-lane rural highway, but because of limited funds the 18-ft. width still predominates on state and federal-aid improvements. The mileage of 20-ft. pavement, however, is increasing each year, and during the past year 20 per cent of the mileage of hard pavements on federal-aid projects was of this width and 70 per cent was 18 ft. wide. The free flow of traffic on highways through villages and built-up sections requires a pavement width of at least 36 ft. where parallel parking is permitted and 50 ft. where diagonal and right-angle parking is permitted.

*Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio.

**Transverse Distribution of Traffic.**—The most recent studies of transverse distribution of traffic on highways of various widths are those made in connection with the Cleveland survey. The distribution of passenger-car, truck, and bus traffic was reported for pavements, the width of which ranged from 18 to 40 ft. The total pavement width, where observations were recorded, was divided into 1-ft. lanes, with painted identification markings. With the passage of each vehicle the 1-ft. lane within which its right rear wheel passed was recorded. These data form the basis of the studies of transverse distribution of motor-vehicle traffic on straight and level highway pavements in the various width classes made during the month of November, 1927.

**Summary of Speed Limitations**

| Legal Speed (per Hour) | Number of States 1918 | Number of States 1928 |
|---|---|---|
| 15 miles | 1 | 0 |
| 20 miles | 5 | 1 |
| 25 miles | 20 | 2 |
| 30 miles | 11 | 6 |
| 35 miles | 2 | 22 |
| 40 miles | 1 | 10 |
| 45 miles | 0 | 4 |
| 50 miles | 0 | 0 |
| No limit | 8 | 3 |

Table I is typical of the results obtained outside of the urban area. There was found to be a marked difference

**Table I.—Transverse Distribution of Passenger-Car Traffic on Highway Pavements in the Cleveland Regional Area**

| Highway | Surface width | Direction of traffic | Total passenger cars observed | Distance from edge of surface (feet): 1 | 2 | 3 | 4 | 5 | 6 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Right rear wheel passages, percentage of total number | | | | | | |
| Cedar Road, east of Warrensville Center Road | 18 | East | 1,069 | 1.5 | 12.0 | 21.3 | 25.3 | 13.6 | 8.9 | 82.6 |
| | | West | 931 | 1.5 | 15.7 | 31.9 | 26.1 | 14.1 | 4.0 | 93.3 |
| West Lake Road, west of Wagar Road | 20 | East | 1,304 | .5 | [1] 3.8 | 17.2 | 33.5 | 23.4 | 8.6 | 87.0 |
| | | West | 1,042 | 2.5 | 19.5 | 41.9 | 23.6 | 4.8 | 1.3 | 93.6 |
| Northfield Road, south of Forbes Road | 20 | North | 620 | 1.9 | 13.9 | 32.7 | 27.7 | 12.9 | 3.4 | 92.5 |
| | | South | 806 | ........ | [2] 2.1 | 13.9 | 27.2 | 21.6 | 10.1 | 80.9 |
| Euclid Avenue,[3] east of Chardon Road | 18.7 | East | 1,403 | ........ | .8 | 2.1 | 3.7 | 6.5 | 8.3 | 21.4 |
| | | West | 1,376 | ........ | .6 | 3.5 | 6.7 | 9.7 | 13.5 | 34.0 |
| Euclid Avenue,[3] west of Chardon Road | 18.7 | East | 2,328 | ........ | .6 | .7 | 4.3 | 11.0 | 9.0 | 25.6 |
| | | West | 2,354 | ........ | .7 | 4.8 | 10.7 | 10.7 | 9.1 | 36.0 |
| Detroit Avenue, east of Clague Road | 32 | East | 2,000 | .1 | ........ | .3 | 1.4 | 6.0 | 16.6 | 24.4 |
| | | West | 1,668 | .1 | .2 | .3 | 1.9 | 8.1 | 11.0 | 21.6 |
| Franklin Avenue,[4] east of West Sixty-fifth Street | 32 | East | 2,948 | .1 | .3 | 2.1 | 6.0 | 12.1 | 16.3 | 36.9 |
| | | West | 2,095 | ........ | .3 | 1.7 | 4.6 | 10.6 | 16.5 | 33.7 |
| Lake Shore Boulevard, east of Harland Avenue | 38 | East | 1,334 | .0 | .7 | 2.4 | 8.0 | 9.6 | 11.0 | 31.7 |
| | | West | 1,803 | .1 | .1 | .9 | 3.1 | 4.3 | 6.6 | 15.1 |
| United States route 20, east of Wickliffe | 40 | East | 1,081 | .0 | .0 | .0 | .5 | .7 | 4.0 | 5.2 |
| | | West | 1,094 | .0 | .0 | .8 | .6 | 4.1 | 7.4 | 12.9 |
| Bulkley Boulevard,[5] east of Center Parkway Section | 40 | East | 8,183 | .2 | 1.1 | 7.3 | 18.2 | 13.0 | 6.5 | 46.3 |
| | | West | 4,702 | .0 | .1 | 1.4 | 5.5 | 12.7 | 15.7 | 35.4 |

[1] A letter box located close to the edge of pavement accounts for the low percentage in the second foot lane, east direction of traffic.
[2] A 6-inch raised curb accounts for the low percentage in the second foot lane, south direction of traffic.
[3] Each direction is used for 2-way traffic and is separated by a gravel strip 18.5 feet in width.
[4] Used as a 3-lane road during peak-hour traffic; the inbound, or outbound peak traffic, uses 2 lanes during peak hours. Lanes are not separated by markings.
[5] Roadway width separated into 4 marked lanes, each 10 feet in width. Inbound or outbound peak traffic uses 3 lanes during peak hours.

between the transverse distribution of the right rear wheel passages of passenger cars on pavements 18 and 20 ft. in width and similar data on pavements in excess of 20 ft. in width but not wide enough for four lanes of traffic. On the 18 and 20-ft. surfaces over 80 per cent of the passenger-car traffic traveled 6 ft. or less from the edge of the pavement. For surfaces in excess of 20 ft. the highest percentage of utilization of the section within 6 ft. of the edge of the pavement was 46.3.

On pavements over 20 ft. in width, truck and bus traffic fail to utilize to any extent the 3 ft. nearest the edge on each side of the pavement. With an increase in width there is an increasing tendency for motor-vehicle traffic to operate more toward the center of the pavement.

Passenger cars on an 18-ft. highway when passing vehicles moving in the opposite direction travel approximately 1 ft. nearer the edge of the pavement than when they are not passing other vehicles.

The average clearance between passing cars on an 18-ft. pavement is approximately 1 ft., while on a 20-ft. pavement the average clearance ranges from 1.9 to 2.4 ft. On both 18 and 20-ft. pavements, drivers of passenger cars apparently prefer to sacrifice clearance rather than drive close to the edge of the pavement.

The average distance of rear-wheel passages of passenger cars from the edge of the pavement on 32, 38, and 40-ft. highways is over 8 ft. The average clearance of passenger cars passing in opposite directions ranges from 6.7 ft. on the 32-ft. pavement to 11.7 ft. on the 40-ft. road.

**Conclusions on Highway Width.**—The following conclusions as to width of highway were presented in the report on the plan of improvement for the Cleveland regional area:

1. The roadway surface for all 2-lane roadways should be 20 ft., exclusive of space for parked vehicles. Roadways of 18-ft. width in good condition are classed as satisfactory, but these should be widened to a minimum of 20 ft. when reconstruction is necessary. Surfaces less than 18 ft. in width should be widened to a minimum of 20 ft. as rapidly as conditions permit except in the case of extremely light traffic routes where the widening is less urgent.

2. Normal distribution of traffic requires an even number of traffic lanes. When the volume of traffic exceeds the capacity of a 2-lane roadway a 4-lane roadway (approximately 40 ft.), exclusive of space for parked vehicles, is recommended. The 3-lane roadway is found satisfactory in a few cases where there are very pronounced peak periods of traffic in alternate directions at different periods of the day and particularly when the acquisition of right of way for a 4-lane roadway is extremely difficult or prohibitive in cost. The 3-lane roadway, when used, requires lane marking and careful traffic control.

3. All roadways designed for more than two lanes of traffic should have complete lane marking, and provisions should be made for regulation of traffic in conformity with the lane marking.

4. Assuming that the roadway is designed for the accommodation of moving traffic, the choice of any width between 20 and approximately 40 ft., except in the relatively few cases where the 3-lane roadway is satisfactory, is normally uneconomical, as the excess of width above 20 ft. adds but little to the traffic capacity of the roadway. If the additional width is intended to provide space for parking such widths as 22, 24, and 27 do not permit parking without obstruction of the normal traffic lanes.

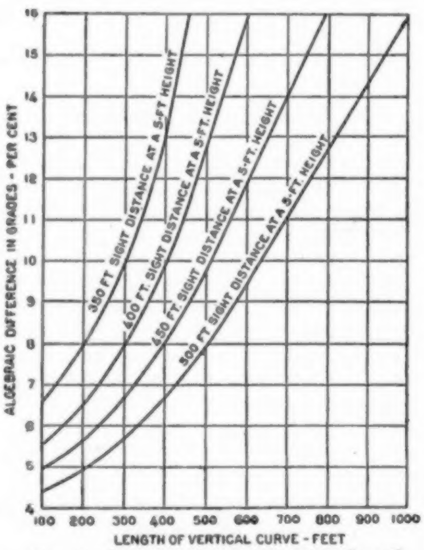


**Fig. 1.—Diagram for Determining Length of Vertical Curve for Required Sight Distance**

5. Under open-road conditions—i. e., through areas outside of suburban development—with little local traffic and relatively infrequent cross routes, the normal traffic capacity of a 2-lane roadway, at a traffic speed of 25 miles per hour, is approximately 10,000 vehicles per day. In suburban sections, with parking adjacent to the roadway surface and a larger volume of cross traffic and local traffic, the capacity of a 2-lane roadway is reduced to approximately 8,000 vehicles per day. An abnormally high proportion of large-capacity trucks, buses, or other slow-moving vehicles will decrease these limits.

**Shoulders.**—With the improvement in motor cars and equipment, emergency roadside repairs are less frequent than formerly, but one such obstruction in a mile of heavily traveled road creates a serious danger, and shoulders of 6 or 8 ft. should be provided for parking and repairs. In mountainous country the cost of wide shoulders is extremely heavy, and in many cases shoulders 3 or 4 ft. wide are being built, while in other sections of the country shoulders 10 ft. wide are the rule, but the predominating practice appears to be 6 ft.

**Right of Way.**—During the past few years there has been a noticeable trend toward the acquisition of wider right of way, especially at intersections of important highways. Rights of way 100 and 200 ft. wide are not uncommon, although the majority of states are still acquiring less than 100 ft. The acquisition of right of way at intersections prevents the obstruction of view by private construction, such as filling stations, lunch stands, and roadside markets.

**Sight Distance.**—The increase in volume and speed of traffic has made necessary greater sight distances on both horizontal and vertical curves. It is desirable to maintain a sight distance of at least 500 ft., but this is not always feasible on mountain roads. A traffic line should be marked along the center of the road at all convex vertical curves.

A few years ago it was the rule to use a vertical curve only where the algebraic difference on grade was 2 per cent or more. Vertical curves are now used at almost every change in grade, although some engineers use them only at changes of five-tenths or more.

**Curves.**—No general rule can be given for determining the minimum radius of horizontal curvature. In mountain location curves of 100-ft. radius are sometimes necessary, whereas in the flatter sections of the country curves of 1,000-ft. radius are the prevailing practice. During the past year the predominating minimum radius of curvature on Federal-aid projects has been about 500 feet. Figures 1 and 2 are diagrams for determining sight distances on vertical and horizontal curves which should be useful in design.

**Grades.**—On main-line highways it is customary to adopt a maximum grade of 5 per cent in gently rolling country and 7 per cent in rough country, but it is no longer considered good practice to resort to sharp curvature in order to avoid grades somewhat steeper than 7 per cent. If local conditions permit either a 7 per cent grade with a sharp curve or a short 9 per cent grade with a wider curve, the latter design is thought to be the better practice because it is safer for modern motor traffic.

There is a difference of opinion among engineers as to whether, in gently rolling country, the grades should follow the general topography with very little cutting and filling or whether railroad practice should be followed with long easy grades involving cutting at every hill and filling every valley. A few years ago, when the cost of grading was a large part of the total cost of the improvement, the use of railroad grades made a considerable difference in the cost, but at the present time it is a smaller percentage of the total cost, and there is, therefore, not as much tendency to cheapen

the design in this direction. There is a lack of agreement among authorities as to the relative economy of operating motor vehicles on the two kinds of grades, and the subject is one which warrants further investigation. Studies made at Iowa State College† are somewhat favorable to rolling grades.

The top or weathered zone in many soil types is more stable than certain of the unweathered zones. Under these conditions, and when the weathered zone has appreciable thickness, subgrades located close to the original ground surface are apt to be more stable than those located in deep cuts and fills. Usually, however, it is not advisable to lay a grade line so as to consistently take advantage of this fact.

†Agg, T. R. Economics of Highway Grades, Bul. 65, Engineering Experiment Station, Ames, Ia.

**Compensation of Grades for Curvature.**—It is customary to compensate grades over 5 per cent on curves of less than 500-ft. radius to permit unretarded ascending speed on curves. The amount of compensation depends on local conditions, but a general rule followed by many engineers is to reduce the grade one-half of 1 per cent for each 50 ft. of reduction in radius below 500 ft.

**Superelevation and Widening.**—When highway curves were first superelevated there was considerable opposition from the users of horse-drawn vehicles, because they felt that superelevation was primarily for the purpose of converting the highways into automobile speedways. Now, that superelevation has become general there is little opposition to a conservative practice, but in some cases a degree of superelevation is used which is excessive for slow-moving vehicles. A maximum superelevation of 2 in. per foot of width as called for on some plans is questionable, and the standard recommended by the American Association of State Highway Officials with a maximum of 1 inch per foot of width appears to agree with the consensus of opinion among highway engineers.

Various experiments have been tried in superelevating for mixed traffic, using a compound cross section instead of the usual straight section, and it is possible that a solution of the problem will be worked out along this line. The formula recommended by the American Association of State Highway Officials is:

$$E = 0.067 \frac{V^2}{R}$$

where $E$ = maximum elevation in feet per foot of width,
$V$ = the velocity in miles per hour (35 recommended), and
$R$ = radius of curve in feet.

Figure 3 presents a graphic solution of this formula with the limits indicated.

In eight states curves of 1 deg. or more are superelevated, but in the majority of states superelevation is used only on curves of 3 deg. or more. There is no standard practice for developing the superelevation, but the majority of states start the banking from 100 to 200 ft. ahead of the point of curvature and reach full superelevation at the same distance inside the curve. There are several states, however, that reach full superelevation at the point of curvature.

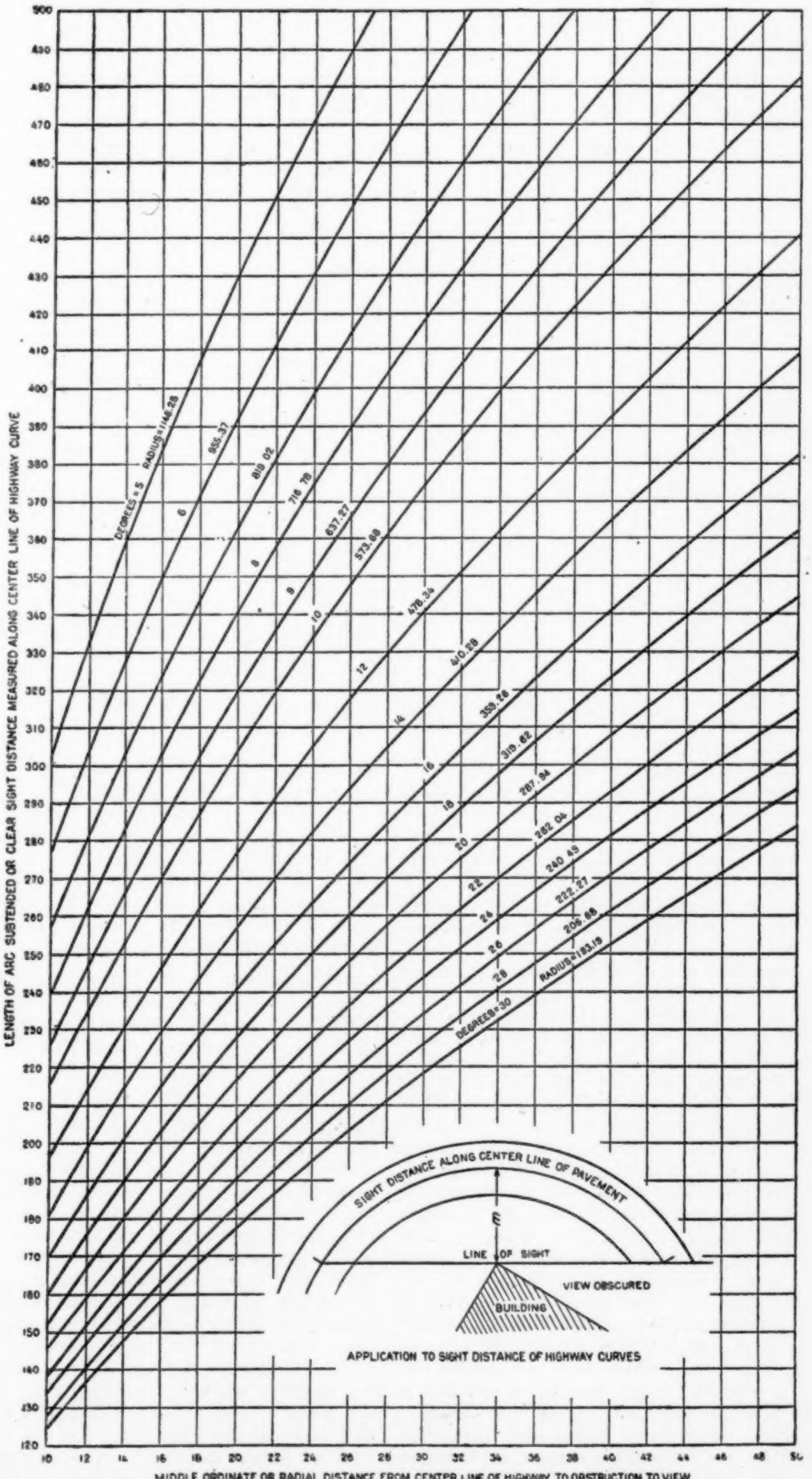



**Fig. 2:—Diagram for Determining Length of Unobstructed View Along Center Line of Highway for Various Degrees of Curvature and Radial Distances from Center Line to Obstructions to Line of Sight**

Curves are usually widened where the curvature is 8 deg. or more. The Voshell formula for widening, recommended by the American Association of State Highway Officials is as follows:

$$W = 2(R - \sqrt{R^2 - L^2}) + \frac{35}{\sqrt{R}}$$

where $W$ = the widening in feet,
$R$ = the radius of curve in feet, and
$L$ = the wheel base of the vehicle in feet (20 recommended).

The majority of states start the widening 50 to 100 ft. ahead of the point of curvature and reach the full widening at the same distance inside the curve. A few states reach full widening at the point of curvature. Most states use the parabolic spiral transition, although a few states use a straight-line transition. Widening of the pavement has become less important where sharp curves are not used, and one state has abandoned widening of the pavement as standard practice.

**Compound and Reverse Curves.**—Compound curves were frequently used up to the past few years, but it is now recognized that they are dangerous for fast-moving traffic if there is considerable difference in the radii. When a vehicle passes from a slow to a rapid rate of curvature, a change in steering and often a change in speed are required immediately. Failure to sense the changed condition, which is most likely to happen at night, may result in an accident. Usually a tangent section can be used between the curves of different radii; or better still, a simple curve can be used throughout.

Reverse curves were considered objectionable with the speed limits in force in 1918 and are now considered very dangerous. The danger is due not only to the sudden change in direction of curvature, but also to the fact that superelevation can not be provided at the transition point. A tangent section 200 ft. long between the curves will permit proper transition with superelevation and widening.

**Crown and Smoothness of Surface.**—Smoothness of road surface is now emphasized much more than formerly, and most specifications require a surface finish with a maximum tolerance of ¼ in. under a 10-ft. straight edge. With such surface trueness it has been possible to reduce the crown to a very small amount, and at the present time 1/8 to 1/10 in. per foot is the prevailing practice.

It is noticeable that some states are more successful than others in building smooth riding pavements, even where the specifications as to finish are the same, and it is obvious that only the greatest care in finishing will produce the results desired. During the past year the machine finisher has been tried on bituminous pavement construction, and apparently greater trueness of surface is produced than by the usual hand-raking methods.

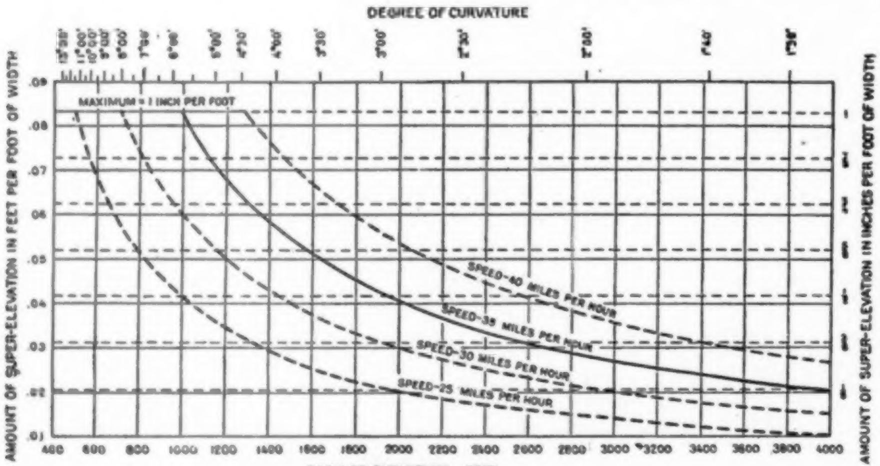



**Fig. 3.—Superelevation of Curves Required According to Formula R ecommended by the American Association of State Highway Officials**

**Acknowledgment.**—The foregoing is an abstract of a report in March issue of Public Roads, the official publication of the U. S. Bureau of Public Roads.

**Uruguayan Road Program Revenue Provided.**—A revenue act providing for funds for carrying out the 6-year port and road development program was passed by the Uruguayan Congress during the last quarter of 1928. Under this development program $13,895,000 will be available for highway improvement as follows: Bridge construction, $3,914,000; macadam road construction, $2,884,000; transformation of macadam and bituminous roads to concrete, $927,000, and in improving dirt roads $6,180,000. Further information on the Montevideo-Colonia project may be obtained upon application to any of the District Offices of the Bureau of Foreign and Domestic Commerce or to the Automotive Division at Washington, D. C.

## "Road Hogging" Cause of Many Accidents

"Road-hogging" was responsible for 328 motor vehicle accidents, including five fatalities or more than 50 per cent of the 589 Sunday accidents in January, according to Benjamin G. Eynon, registrar of motor vehicles, Pennsylvania Department of Highways. Careless motorists, failing to signal, were responsible for 127 Sunday accidents and speeders were responsible for 45 accidents, including two fatal ones, or one-eighth of the Sunday totals.

In 117 accidents, including two fatal ones, the motorists responsible were on the wrong side of the road; in 133 accidents, including two fatal ones, offending motorists did not have the right-of-way; in 50 accidents, including a fatal one, motorists "cutting in" were responsible; seven accidents resulted from motorists passing on curves or hills and 21 accidents resulted from passing on the wrong side of the road.

Commenting on these accidents, Registrar Eynon said: "The road hog, unquestionably, was responsible for more than one-half of the Sunday accidents in January. Failure to 'keep to the right of the road,' our accident reports demonstrate, beyond a question of a doubt, was responsible for these motor accidents. A strict adherence to the law and a due regard for the rights of other motorists would have done much to reduce these traffic Sunday casualties.

"Another curious fact in connection with Sunday accidents is the record of 76 accidents, including seven fatal ones, or one-fifth of the Sunday totals, in the hours between 12 and 6 a. m. when traffic was lightest. Most of the accidents in these hours, our reports show, were caused by Saturday motorists returning home. Laws may punish but they cannot prevent 'road-hogging,' and it is only too true that the 'road hog' often causes fatal accidents before he is caught or detected.

"The lesson to be drawn from these Sunday accidents cannot be overemphasized for they demonstrate the need of courtesy, a greater regard for the safety of life and limb, and more unselfishness in driving."

**School for Highway Engineers in Italy.**—Through a private donation it has been possible to establish a Department of Highway Engineering at the Royal Italian Engineering School. The donation amounts to $26,300 payable in ten annual amounts of $2,630 each. The donor, Commendatore Vaselli, the head of a local highway construction firm also places his workshops and offices at the disposal of the students to enable them to study the practical construction of highways, as well as other technical construction problems.

# Fundamentals of Bridge Type Analysis

## Comparison of Two Bridge Decks Used as Example

BRIDGE crossing sites offer problems to bridge and highway engineers which in the past have too often been solved by a rule of thumb method or arbitrary selection. There is an economic type of bridge for every crossing. Selection of that type is the problem to which reference was made above. In order to select the economic span the engineer should investigate or survey his problem from a broad viewpoint. A remark has often been made that some designers cannot see the whole problem because of the detail; i. e., they could not see the forest because of the trees. Type selection requires the engineer to survey the whole field, to stand off on some hill or in an airplane, as it were, and look at the forest.

A recent book by Mr. C. B. McCullough entitled, "Economics of Highway Bridge Types," which has just been published by the publishers of Roads and Streets, treats of this problem in a thoroughgoing manner. The following comparison of bridge decks from that book shows how the problem of type selection is accomplished.

Let it be required to determine the relative economy of a reinforced concrete deck versus a 6-in. laminated timber deck for a 200-ft. steel span under the following conditions as regards design, unit first costs, and volume of traffic.

Length of structure........................200 ft.
Width of roadway........................ 20 ft.
Cost of 6-in. laminated timber deck in place ........................................$50 per M
Cost of reinforced concrete deck in place (including reinforcing metal) ..........................................$33 per cubic yard
Average traffic........500 vehicles per day
Thickness of concrete deck (average) ..........................................................7 in.

From the above figures the following additional data may be developed:

Approx. total cost of 6-in. laminated timber deck (including wheel guards).................................$1,280
Approx. total cost of reinforced concrete deck (including curbs) ............................................................ 3,420

The first step in the analysis is the determination of the probable annual maintenance costs for the above types. These data are obtained from maintenance records where available and plotted in curve form. Fig. 2 is a series of curves plotted through results obtained from the writer's maintenance cost records. The upper curve represents the average yearly maintenance costs on timber decks under the most adverse conditions; the lower curve represents average maintenance costs for timber decks under the most favorable conditions.

These curves are for timber decks wherein the service period is limited and determined by the deterioration of the timber due to decay rather than by traffic wear. Laminated decks, in general, resist traffic wear much better than plank decks owing to the fact that the decking pieces are laid with vertical grain. This type of decking under a traffic of less than about 500 to 600 vehicles per day (except for heavy trucking) will wear rather evenly and may be maintained at the costs indicated in Fig. 2 until progressive deterioration from decay increases the maintenance cost above the point of economy. For plank decks under extremely light traffic this condition may also hold but, in general, for traffic above 200 vehicles per day the roadway surface becomes too rough for traffic use long before decay has seriously affected the decking pieces. The curves of Fig. 2, therefore, would not apply to plank decks except for very light traffic.

With the above understanding the curves of Fig. 2 may be used for the purposes of the problem at hand.

These yearly maintenance cost curves are next superimposed upon an annual renewal cost curve as a base. The results are given in Fig. 3. The upper and lower curves of Fig. 3 represent what may be regarded as the extreme range in conditions for laminated timber decks in the locality and for the traffic conditions covered by these data (for other conditions curves varying somewhat from these will doubtless be obtained). Now, it is apparent that for all intermediate conditions, the combined cost of maintenance and renewal will be somewhere between these two extreme values as shown diagrammatically by the dotted line in Fig. 3. A study of the actual conditions in any individual instance will enable the engineer to make an interpolation reasonably close to the truth.

Constants for Solution of Equation

Total Annual Cost $C\left[r+\frac{M}{C}+\frac{R}{C}+\frac{I}{C}-P\right]+\left[O+O'\right]$

(R-computed on basis of $3\frac{1}{2}$%)

| Type | M/C % | R/C % | I/C % | Interest @ 5% $[r+M/C+R/C+I/C-P]$ | | | | Interest @ 6% | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | P=2% | P=1% | P=½% | P=0 | P=2% | P=1% | P=½% | P=0 |
| Timber Trestles Group I (Conditions favorable to minimum service life) | 3.7 | 8.5 | 0.2 | 15.4 | 16.4 | 16.9 | 17.4 | 16.4 | 17.4 | 17.9 | 18.4 |
| | | | 0.3 | 15.5 | 16.5 | 17.0 | 17.5 | 16.5 | 17.5 | 18.0 | 18.5 |
| | | | 0.5 | 15.7 | 16.7 | 17.2 | 17.7 | 16.7 | 17.7 | 18.2 | 18.7 |
| Timber Trestles Group II [Conditions favorable to max. service life] | 4.0 | 4.0 | 0.2 | 11.2 | 12.2 | 12.7 | 13.2 | 12.2 | 13.2 | 13.7 | 14.2 |
| | | | 0.3 | 11.3 | 12.3 | 12.8 | 13.3 | 12.3 | 13.3 | 13.8 | 14.3 |
| | | | 0.5 | 11.5 | 12.5 | 13.0 | 13.5 | 12.5 | 13.5 | 14.0 | 14.5 |
| Unhoused Timber Trusses Group I (Conditions favorable to min. service life) | 2.0 | 7.0 | 0.2 | 12,2 | 13.2 | 13.7 | 14.2 | 13.2 | 14.2 | 14.7 | 15.2 |
| | | | 0.3 | 12.3 | 13.3 | 13.8 | 14.3 | 13.3 | 14.3 | 14.8 | 15.3 |
| | | | 0.5 | 12.5 | 13.5 | 14.0 | 14.5 | 13.5 | 14.5 | 15.0 | 15.5 |
| Unhoused Timber Trusses Group II (Conditions favorable to max service life) | 2.0 | 5.3 | 0.2 | 10.5 | 11.5 | 12.0 | 12.5 | 11.5 | 12.5 | 13.0 | 13.5 |
| | | | 0.3 | 10.6 | 11.6 | 12.1 | 12.6 | 11.6 | 12.6 | 13.1 | 13.6 |
| | | | 0.5 | 10.8 | 11.8 | 12.3 | 12.8 | 11.8 | 12.8 | 13.3 | 13.8 |
| Housed Timber Truss Spans. | 3.0 | 3.2 | 0.2 | 9.4 | 10.4 | 10.9 | 11.4 | 10.4 | 11.4 | 11.9 | 12.4 |
| | | | 0.3 | 9.5 | 10.5 | 11.0 | 11.5 | 10.5 | 11.5 | 12.0 | 12.5 |
| | | | 0.5 | 9.7 | 10.7 | 11.2 | 11.7 | 10.7 | 11.7 | 12.2 | 12.7 |
| Steel Construction | 2.2 | 1.0 | — | 6.2 | 7.2 | 7.7 | 8.2 | 7.2 | 8.2 | 8.7 | 9.2 |
| Concrete Construction | 1.4 | 0.7 | — | 5.1 | 6.1 | 6.6 | 7.1 | 6.1 | 7.1 | 7.6 | 8.1 |

**Fig. 1.—Constants for Solution of Equation**

Let it be assumed that, for the conditions at hand, the most probable assumption as to yearly maintenance plus renewal costs is 12½ per cent.

Maintenance and renewal costs for concrete construction are shown by Fig. 1 to average 2.1 per cent. This figure is for concrete construction in general. For concrete bridge floors the maintenance costs run somewhat higher so that a value of 3 per cent for renewals plus maintenance may be assumed for the purpose of this problem. (If actual maintenance costs are available for concrete floors as a class, curves similar to Figs. 2 and 3 should be plotted for the same.)

With the above data and assuming an insurance rate of 0.2 per cent for the laminated decking the total annual costs to the state may now be calculated as follows (neglecting any consideration of rental values):

Annual cost to state=

$$C\left[r+\frac{M+R}{C}+\frac{I}{C}\right]$$

For the two types of deck this equation reduces to the following:

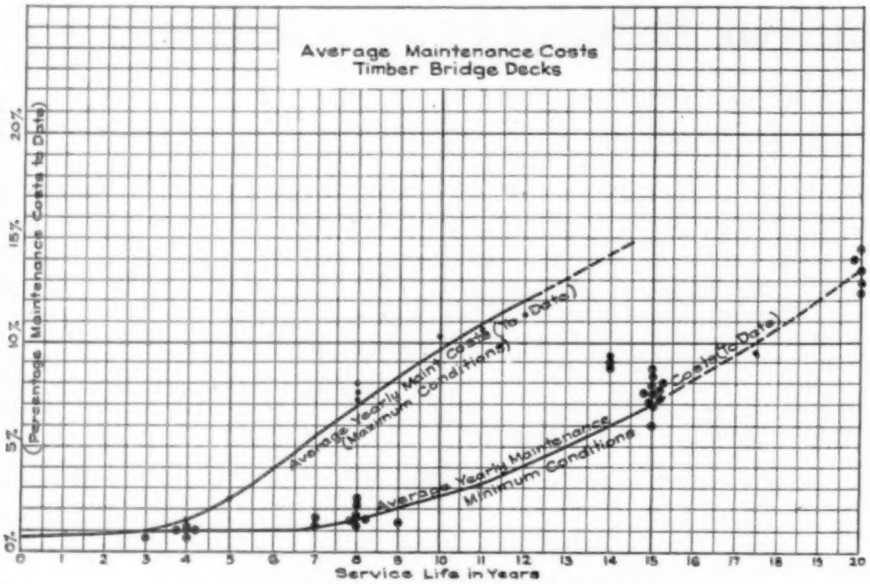



Fig. 2.—Average Maintenance Costs Timber Bridge Decks

Annual cost of laminated deck= \$1,280 [5%+12.5%+.2%]=(\$1,280.00) (17.7%)=\$226.50.

Annual cost of concrete deck=\$3,-420.00 [5%+3%]=\$273.60.

From the standpoint of the state it is thus seen that the most economical construction is the timber decking. However, as discussed in Chapter III of McCullough's book, the total annual cost of any construction must include not only those costs accruing to the state but also the costs accruing to traffic.

Using the figures given for traffic costs in Chapter III of "Economics of Highway Bridge Types," the cost of operation may be calculated as follows:

For the laminated timber deck

$$O=(500)\ (365)\ \frac{200}{5280}\ (\$.102)=\$705$$

For the concrete deck

$$O=(500)\ (365)\ \frac{200}{5280}\ (\$.08)=\$554$$

From the above figures the following combined costs are derived:

For the laminated timber deck

Total annual cost=\$226.50+\$705= \$931.50.

For the reinforced concrete deck

Total annual cost=\$273.60+\$554= \$827.60.

If the above assumptions are correct the timber decking will prove economical until traffic has reached a density value $D$ given by the equation:

$$\frac{(365)\ (200)\ (.102-.08)}{5280}$$

$$D=273.60-226.50$$

or $D$=154 vehicles per day.

The above analysis has been used simply to illustrate the proper method of attack and may or may not represent true conditions. It has been assumed that the choice between decking types lies between a 6-in. laminated timber deck and a reinforced concrete deck. This has been done in order to avoid a lengthy discussion. In actual practice, it is quite possible that other decking types would be found to deserve consideration. In any event, however, the method to be followed is the same as outlined above.

It is anticipated, therefore, that with the data given in "Economics of Highway Bridges Types," no difficulty should be experienced in making a correct economic analysis of competing construction types for any highway bridge problem ordinarily encountered in practice.

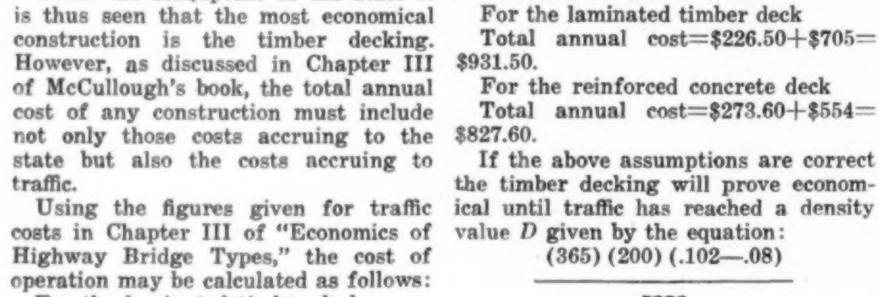



Fig. 3.—Average Maintenance and Renewal Costs Timber Bridge Decks

## Traffic Stripes on Highway Edge

As an added convenience to traffic the California Highway Commission has painted traffic stripes on the edges of a 20 ft. asphaltic concrete pavement between Herndon Bridge and Madera. The striping consists of a white line 6 in. wide along each edge of the pavement and an orange line in the center. Oil mixed rock borders blended in so closely with the pavement that the edge of the roadway was hard to distinguish before the stripes were painted. The present lines define the traffic lanes and tend to speed up traffic considerably, particularly at night.

According to "California Highways and Public Works" the orange line appears to have better visibility at night and in the fog. The white line along the edge is of particular advantage when meeting traffic as it defines the edge of the roadway and is always visible even when meeting a car with glaring headlights.

The center line draws traffic toward the normal driving lane and the side lines act to some extent in keeping it off the shoulders.

The equipment used in marking the highway is a light truck and a Simons Paint Machine. The costs on this work vary according to the type and condition of the surface. A fairly open, porous surface will require as much as 18 gal. of paint per mile while a smooth, "close" surface will use about 13 gal.

Where it is necessary to mark the line before painting, the cost of moving to the job, labor, equipment rental and supplies is about \$15 per mile of line. Where marking in advance is not required, the cost is from \$5.25 to \$6.35 per mile. This makes the total cost range between \$35 and \$55 per mile of line.

# ROADS and STREETS

Published Monthly by

GILLETTE PUBLISHING COMPANY, CONKEY AVE. AND MADISON ST., HAMMOND, IND., AND 221 EAST 20TH ST., CHICAGO

Publishers of

Engineering and Contracting — Roads and Streets
Municipal News and Water Works — Tiles and Tile Work

Road and Street Catalog and Data Book
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Subscription Price $2.00 — Foreign Postage 65c Extra




## Make Our Highways Fool-Proof

When shingle mill owners found that fingers were frequently nipped off, even where operators were skilled men, they installed protective devices that greatly reduced such accidents. Mills and factories have spent millions making all kinds of machinery more nearly fool-proof, and the consequence has been a steady decrease in accidents. But the public does not yet fully realize that the same sort of fool-proofing is badly needed in the highway field. True it is that we have just begun to see that motor vehicle drivers must be protected against their own carelessness in certain places, for we are slowly installing more wigwags at railway crossings, and we are gradually equipping main thoroughfares with stop and go signals. Yet we are woefully slow in adopting these obvious safeguards, and we are still slower in widening roads and streets where traffic congestion results in frequent fatal accidents.

The other day the editor motored 300 miles over a wet road, and saw three automobiles in the ditch. In one case, the car had been crowded off the road. In the other two cases the cars had turned over because the wheels on one side had left the pavement long enough to mire in the muddy shoulders. So in all three cases, narrowness of the hard surface was the cause of the accidents. On this particular road the traffic was not great enough, except near cities, to warrant more than a 20 ft. strip of pavement, but it was sufficient to warrant the building of gravel shoulders fully 6 ft. wide on each side of the pavement. Not one of these accidents would have occurred had such shoulders been provided.

The time has come to stop blaming such accidents upon careless drivers. Too many of them have occurred where the drivers were not careless. But even granting that every highway accident is due to carelessness, the public should be willing to spend enough money to make its highways more nearly fool-proof. In doing this, they would merely be following the precedent set by mill and factory owners, by railway and other public utility companies.

Remember also that however careful you may be as a driver, next Sunday may see you and your family crowded off some narrow roadway and ditched, as was one of the three cars just mentioned; or you may misjudge the position of the edge of the pavement, because of rain or of glare of an approaching headlight, and be ditched as were the other two cars. It is noteworthy that the most careful of drivers often suffer not merely from the carelessness of other drivers but from slight misjudgments of their own.

The most outstanding need is for warning signals at all railway crossings; and next in importance is the building of hard, wide shoulders along narrow pavements. Finally comes the most expensive part of the problem of fool-proofing the roads by widening the pavements even where only holiday and Sunday driving causes traffic congestion. Fortunately this is usually confined to cities and their immediate neighborhoods.

As we recall it, American soldiers killed outright in the world war were fewer in number than citizens killed on our highways during the last three years. Laws have failed to stop this slaughter. Editorials, lectures and preachments of all kinds have apparently had little effect. Has not the time come to start fool-proofing our highways in real earnest?

## The Overestimated Acumen of Most Scientists

When Einstein first published his theory of relativity and the three basic formulas deduced by its aid, there was only one scientist in all the world who wrote him a commendatory letter. That was in 1905, and the lone scientist who approved his theory was Planck, the great German physicist. Not until 1919, after one of Einstein's predictions had been verified by British astronomers, did his theory receive general acceptance.

There is food for thought in this bit of scientific history, and chewing the cud of reflection upon it results in no very complimentary conclusions as to the logical ability of scientists in general. Indeed it leaves an ineradicable impression that something about scientific training is sadly amiss.

Note particularly that two of Einstein's basic relativity formulas had previously been deduced by Lorentz by means of the established electromagnetic theory, and the mathematics used by Einstein in their deduction is far simpler than that used by Lorentz; so simple, indeed, that any college graduate can readily follow it. We may go further, and add that these deductions can be made clear to any high school graduate by any person who understands the deductions and the art of teaching. So it will not do to excuse scientists for their slowness in accepting Einstein's relativity theory, either on the ground that it long remained unconfirmed or on the ground that it was so profound in its mathematics as to be beyond most scientists. Einstein's third formula in the original trinity did involve difficult mathematics, but an excellent comprehension of his relativity theory can be had by any one who understand the derivation of even one of the three basic formulas.

There are but four inferences from the almost universal silence that greeted Einstein's original publications on relativity: (1) That his publications were read by very few scientists; (2) that many of those who read did not understand; (3) that of those who under-

stood only one had the courage of his understanding, and therefore endorsed the theory; and (4) that the agreement of two of Einstein's formulas with those of Lorentz was not regarded as proof of the truth of Einstein's theory.

Take whichever of these inferences you please, ponder it a little and you will find it anything but flattering to the scientists of the world.

Let us take the fourth inference, since it is perhaps the one most easily defended. Einstein deduced two formulas that precisely agreed with two previously deduced by the aid of an established electrical theory. Does such a deduction by Einstein constitute proof of the correctness of his relativity theory? Unequivocally, and emphatically, yes. Even slight acquaintance with the laws of probability shows the exceeding improbability that two complex quantitative relations can be deduced from false premises and still agree exactly with two other deductions from premises established as true. We say two formulas, but even if such an agreement related only to one such formula the probability of its truth would be overwhelming.

Great, therefore, as was the probability that Einstein's theory was correct, he himself used it to explain, with precision, an astronomical fact that before had lacked explanation. We refer to the rotary motion of the perihelion of Mercury around the sun. It had been found that it travelled about two-thirds of a degree of arc per century in excess of the amount of motion deducible by the Newtonian theory. Einstein thought that his theory could be used to explain this motion, so he applied it, and found that his formula gave 42.9 secs. of arc, whereas the actual unexplained motion was 40.1 secs. plus or minus 1.4 secs. per century. Russell says in his Astronomy: "The agreement between observation and the new (relativity) theory is striking." Obviously so, yet instead of accepting such a correlation as proof conclusive, astronomers struggled to explain it away, for example, by assuming that the attraction of a diffused mass of meteoric matter surrounding the sun could produce the same effect. Note here that if you are permitted to assume the existence of forces of any desired magnitude and direction, you can "prove" almost anything; but that such "proof" is logically valueless unless you can deduce from the same assumptions other facts not involved in making the original assumptions. This form of spurious "proof" that was invented to discredit the relativity theory itself stands as eloquent evidence of the weakness in research logic that characterizes so many scientists.

Fortunately Einstein not only "predicted backward" (as in the instance just cited) but he "predicted forward." He told the astronomical world that rays of light gravitate as if they possess mass, and he predicted just how much a stellar ray of light passing near the sun would be pulled out of line. For a ray that grazes the sun his predicted deflection was 1.75 sec., and for other rays it is inversely proportional to the least distance of approach to the sun's center. Several years after this prediction was made British astronomers found (1919) that stellar rays grazing the sun were deflected 1.98 secs.; and in 1922 American astronomers found a mean deflection of 1.78 secs. plus or minus 0.11 secs., which is "in almost exact agreement with prediction."

It was these verifications of Einstein's predictions that brought the scientific world to his feet; but note the dates (1919 and 1922) and compare them with the date of publication of his original theory (1905). Then ask yourself where was the logic of scientists sleeping during all that period.

The bald truth is that research logic does not exist as a comprehensive science even today, three hundred years after modern research was born. Here and there a research genius works by what men call intuition, guided by a very few formulated principles of research logic; and perhaps such geniuses have evolved a research logic of their own. If so, they do not publish the rules of their logic, but only the results of its application. In the absence of a comprehensive logic of research, those same geniuses usually suffer the greatest of disappointments, for when their discoveries are published, most scientists have so little understanding of methods of testing such discoveries that they either remain silent or fall to wrangling over the merits of the discovery. Almost the only test that they can all understand fairly well, is an experimental or observational test, such as the one made by the astronomers as to the bending of rays of light. But that sort of test is no evidence whatever of logical acumen. Even the ignorant Egyptians of King Tut's time could and did appreciate such tests; for their priests were able to predict eclipses, and the verification of such predictions convinced the most ignorant that the prophetical priests were possessed of a knowledge that seemed divine. Much in the same manner we of today bow reverently before Einstein's theory, now that it has led to correct prediction; and we lack enough logic to see that we should have bowed before it a full generation ago; for, rightly understood, its exact agreement with the results of Lorentz's calculations from established theory alone should have sufficed to establish Einstein's theory. Had doubt still lingered, and had direct observational proof been demanded, then that proof should have been clearly seen in Einstein's deduction of the motion of the aphelion of Mercury; but that it was not seen by many scientists is inferable from the almost universal apathy with which his theory was regarded up to 1919.

Even yet, a "professor of celestial mechanics" in one of our greatest universities, Columbia, scouts at the theory of relativity, and says: "Professor Einstein has hypnotized the world, and everyone is climbing on the bandwagon. * * * * You can never get out of any mathematical equations or formulas anything more than you put into them in the first place. You can not, in reality, prove anything by mathematics."

Where is there a kindergarten in research logic to which may be sent professors who make such statements?

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*Correction.*—In the editorial "Einstein's Deduction of Relationship Between Gravitation and Electrodynamic Forces" in the March issue, an error occurred in relation to the formula:

$e=3r\sqrt[4]{G}$.

It was stated that r=radius of an electron=$10^{-13}$cm. This should have been r=radius of the unit-atom (hydrogen)=$10^{-8}$cm.

H. P. Gillette

## New Type G Portable Two-Piece AggreMeter Plant

The Erie Steel Construction Co., Erie, Pa., have designed a new bin, which will be known as the Type G Portable. This new bin was designed especially for platform operated Aggre-Meters. The bin bottom is off-center, which allows more floor area and shelter for the operator. It is also impossible for the aggregates to arch in a bin of this type because the sides are almost perpendicular.


Portable AggreMeter Plant of Erie Steel Construction Co.

The Type G AggreMeter plant is especially suited for road and general contracting work where portability is essential. It can also be adapted to central mixing plants for loading direct into the mixer hopper. On account of the bin bottom being off-center the mixer can be set under or in front of the bin depending upon conditions. It is built in 60, 73, 74, and 91-ton capacities. The 60 and 74-ton capacities are shipped in two pieces with Aggre-Meter attached, so that it is only necessary to put the two sections together. The top section is flared on two ends only in the 60 and 74-ton capacities. The 73 and 91-ton capacity bins have four flared sides to the top section. It is shipped in two main sections and one top section. The flared top is assembled on the ground and then attached to the top section. Thus the bottom section has the AggreMeter attached and the top section is in two pieces in the 73 and 91-ton capacity plants.

A 60-ton Type G AggreMeter plant can be converted at a later date into a 73, 74, or 91-ton plant by simply adding the correct top section. The 60-ton frame is standard and of ample strength for all sizes of Type G bins. The total weight of the Type G Aggre-Meter plant is divided so that an ordinary crane can handle the sections with ease. They can be moved from place to place on a trailer or flat car. It requires but a short time to attach the top section to the bottom section. The Aggre-Meter plant is then ready for operation.

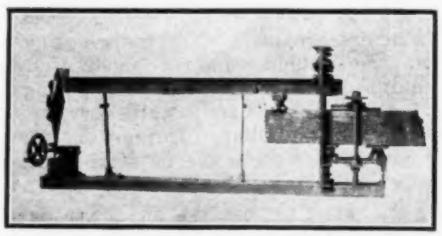
In making this new addition to their line of AggreMetre plants, the Erie Steel Construction Co. feels that they now have a type suitable for every need.

## Tennessee Engineer Develops Testing Machine

A portable cantilever concrete beam testing machine was developed recently by Mr. O. H. Hansard, formerly Engineer of Tests of the Division of Public Works of Tennessee, and Mr. D. D. McGuire, the present engineer. This machine is manufactured by Charles F. Koopman, Jr., 365 Summer St., Boston, Mass., and is called the Hercules Transverse testing machine. The device has been used satisfactorily during the past year by the Tennessee highway department, and especially on the Oakland research project in the vicinity of Memphis. Two such machines broke all the beams on this $25,000 curing research project. Patents have recently been issued to Mr. Hansard and Mr. McGuire covering this machine and the basic principle of a portable transverse testing machine.

The fulcrum which is indicated as a knife edge has been changed to a square, solid block, which gives a definite position of the fulcrum. The location of the three spherical bearings allows the beam with non-parallel faces to be tested without consideration of warp. The upright piece that holds the support for the rear end as the lever arm is made thin, so that there is complete flexibility, and as a load is applied, the rear end of the beam moves forward in the necessary arc so as to prevent restriction of the top fibers of the concrete beam.

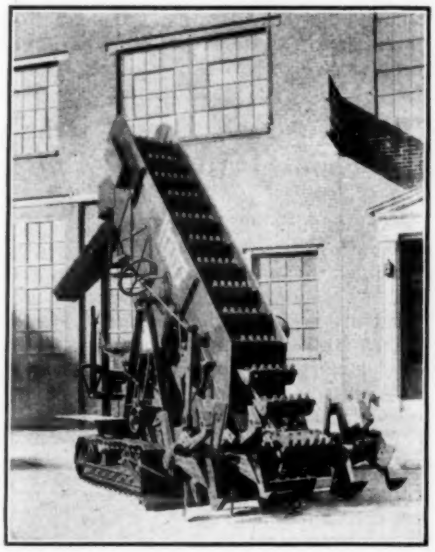
The heavy plate extending from the front of the fulcrum to the center of the rear spherical bearing completely distributes the stress over the top of the beam, making an area of uniformly distributed stress. The load being applied through the knife edge under the lever arm is a pure cantilever load because of the arrangement of bearings and knife edges.



Hercules Transverse Testing Machine

## The New Haiss Excavator

The new Haiss excavator manufactured by the George Haiss Mfg. Co., New York City, is a machine of the bucket dredge type to which has been added a heavy 8-ft. tail shaft with revolving picks and self-feeding propellers of manganese steel. As the tail shaft, driven by the elevator chain, revolves the picks and propellers respectively dig and feed an 8-ft. swath of spoil to the endless chain of manganese steel toothed, alloy steel buckets. The buckets dig in the area not covered by the picks and propellers but because of the fact that the picks have a longer reach the buckets do their work in relatively broken ground and are relieved of any abnormal stresses. Discharge from the buckets goes into a swivel chute which may be directed to the front or to either side of the excavator. The machine is creeper mounted, the mounting being of such width that the entire excavator can travel in its own cut at any grade. Hence, should the particular use warrant, successive cuts may be taken to reach the desired depth of excavation. The capacity of this new tool is 1¾ to 2 cu. yd. per minute working 18 in. deep in an 8-ft. cut and at its crowding speed of about 4 ft. per minute, according to the manufacturer.



New Haiss Excavator

Primarily, the excavator was designed for continuous highway grading preparatory to initial concreting or to road widening but its success in this work has led contractors to use it with equal success on other types of digging. On road grading jobs the machine can be used to clear away any of the usual road bed materials without previous plowing or scarifying. The manganese picks and propellers, by cutting upward, get in under hard packed materials without difficulty and break up the spoil into pieces of a size readily handled by the heavy alloy steel buckets. On other

forms of excavating the digging action is the same and the depth at which a cut may be taken is limited by the grade at which the soil ceases to cave-in at the surface and fall into the cut in front of the machine and since the pick and propeller assembly on the tail shaft is 3 ft. in diameter the machine can cut to at least 4 ft. deep.

The Geo. Haiss Mfg. Co. will be glad to give the details of two types of continuous digging machines to contractors interested in these or similar excavating problems.

## Bucyrus-Erie Diesel Drag Shovel Announced

The new 1-yd. diesel-driven drag shovel announced by Bucyrus-Erie Co. of South Milwaukee, Wis., is easily convertible for use as shovel, dragline, crane or clamshell. For the man who must use several different types of machines this equipment forms a very useful machine with low fuel costs. It uses only 15 to 20 gal. per day of diesel oil which costs only 4 to 10 ct. per gal., depending upon the location.

The machine is built simply and ruggedly. The boom is of latticed channel construction while the dipper handle is a sturdy steel casting of I-beam section. The dipper, built with an extra heavy arch to take the thrust of boom and dipper handle, is built with long, chisel-shaped reversible teeth held in wedge-shaped sockets without bolts or rivets. The teeth are very easy to replace and resharpen. The dipper is made wtih a marked flare to make it easier for the operator to cut a smooth wall and to shorten the time required for dumping.

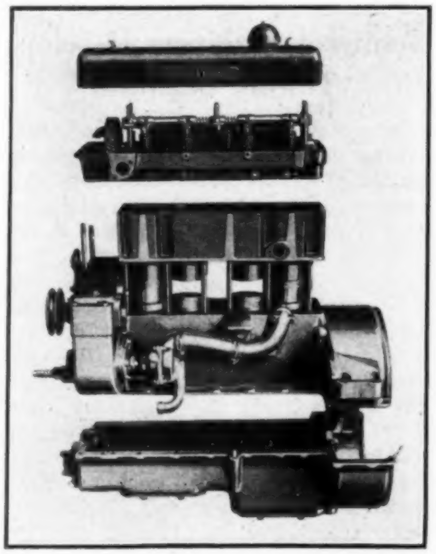
Both hinged bottom and solid dippers are vailable in sizes suited to several widths of trench.

With standard 24-ft. boom and 8-ft. 6-in. dipper handles the machine has a maximum digging depth of 21 ft. and a digging radius of 36 ft. 6 in., according to the manufacturer. The clear dumping height for a front opening dipper is 10 ft. 3 in., they say. The minimum dumping reach of the same dipper, by the same authority, is 19 ft. 6 in., while the solid type dipper dumps between a radius of 17 ft. and a radius of 30 ft.

Bucyrus-Erie Develops New D-2 Diesel Drag Shovel

## New Heavy-Duty Internationals

A new line of heavy-duty International motor trucks with respective ratings of 2½, 3½, and 5 tons has recently been developed. The new trucks are being made in both the chain-drive and double-reduction types with the exception of the 5-ton size which is of chain-drive type only.



Engine Units as Used in New Line

Several important new features are incorporated in the design of these new Internationals, some of which are: new and more powerful engines, four-wheel brakes, single dry-plate clutches with vibration dampers, and transmissions with five forward and two reverse speeds.

The engines of the new Internationals consist of five independently maintained sub-assemblies, which greatly simplify servicing and thus help to keep the truck on the job. It has an overhead valve and camshaft arrangement, which is designed so that valve grinding is a simple bench job, and also made so that lubrication is carried to every moving part. Another important feature of the engine is its aluminum pistons, which are of a patented split-skirt type. Six piston rings are used, three of which are compression rings and the other three of which are oil wipers.

The new Internationals are sturdier in construction and are more powerful in appearance than older models. The frame is heavy and numerous cross-members are used. The main springs on the double-reduction models are equipped with heavy auxiliary springs of the free-end and cantilever type, while the auxiliary springs on the chain-drive models are of semi-elliptic type with free ends.

The steering control on these new trucks is the same patented Steer Easy arrangement, which has been used on Internationals for a number of years.

Reductions in low gear are approximately 100 to 1.

## New Miami Power Operated Bulldozer

A new power operated bulldozer for the Cletrac 30-A which attaches to the Standard Cletrac extended axle has been announced by the Miami Trailer-Scraper Company of Troy, Ohio.

A number of improved features have been incorporated in this bulldozer, since it is entirely independent from the tractor drawbar it does not interfere with the free use of the tractor as a pulling unit and for similar purposes.

The 7-ft. bulldozer blade is carried on H-beams—it is raised and lowered by two steel cables attached at the ends to insure an even lift in places where one end only of the blade is under load. Suitable rub plates eliminate all side movements.

A distinctive feature also is the mounting of the A-frame (which carries the cables) by means of a universal connection direct to the track frame, thus allowing the blade to follow ground contour, minimizing any tendency of the blade to gouge.

The sturdy Miami power winch manufactured for use with this model is so designed that the same winch which operates the bulldozer is also available for power use with the well known Miami one-man power scraper, Miami power pump trailers and the Miami backfiller, as well as the ordinary winch uses.

The Miami winch drives from the power take-off of the tractor with a double roller chain, through a multiple disc clutch designed, integral with an over-running brake which permits the tractor operator, by means of only one lever to control all movements of the load.

This equipment combination provides a tool for every phase of earth moving activity. The Miami company is now engaged in producing similar equipment for a number of various tractor makes and models.

For more detailed information communicate with Mr. E. T. Smith, Miami Tractor-Scraper Co., Troy, Ohio.

Showing New Miami Bulldozer